The Journal of Bone and Joint Surgery

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The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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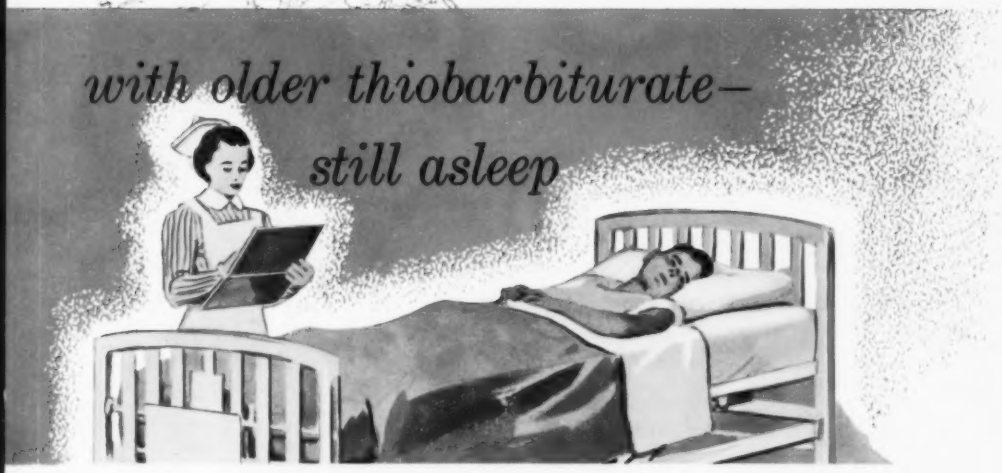

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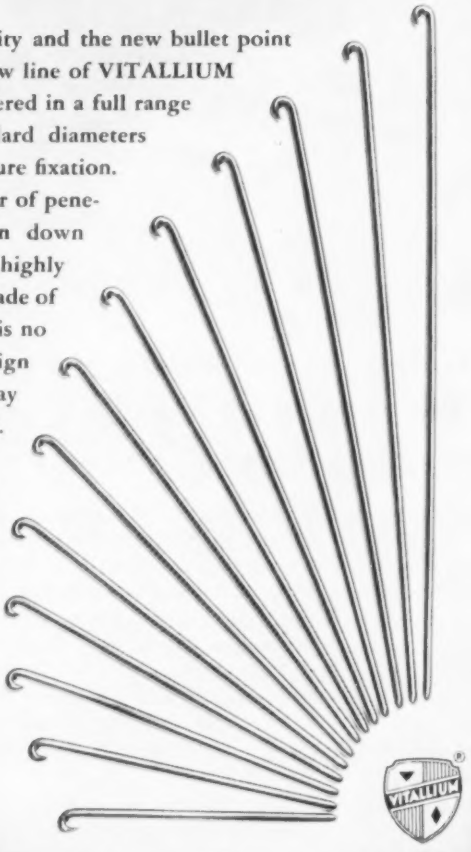

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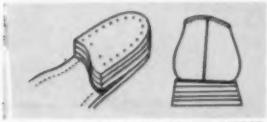

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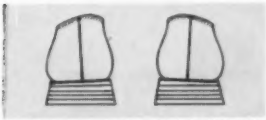

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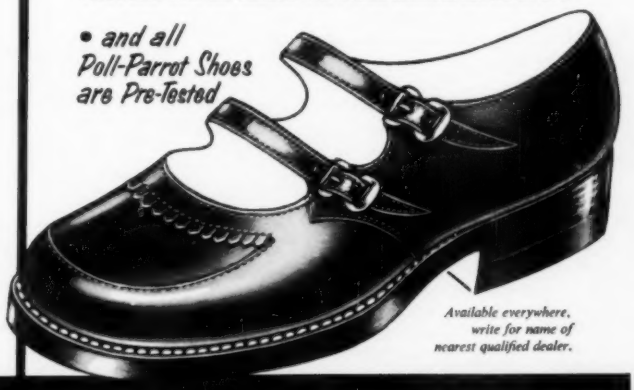

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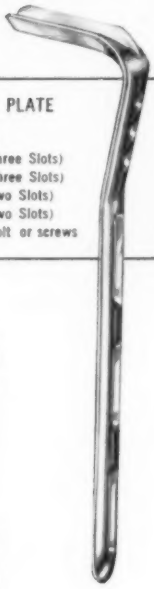

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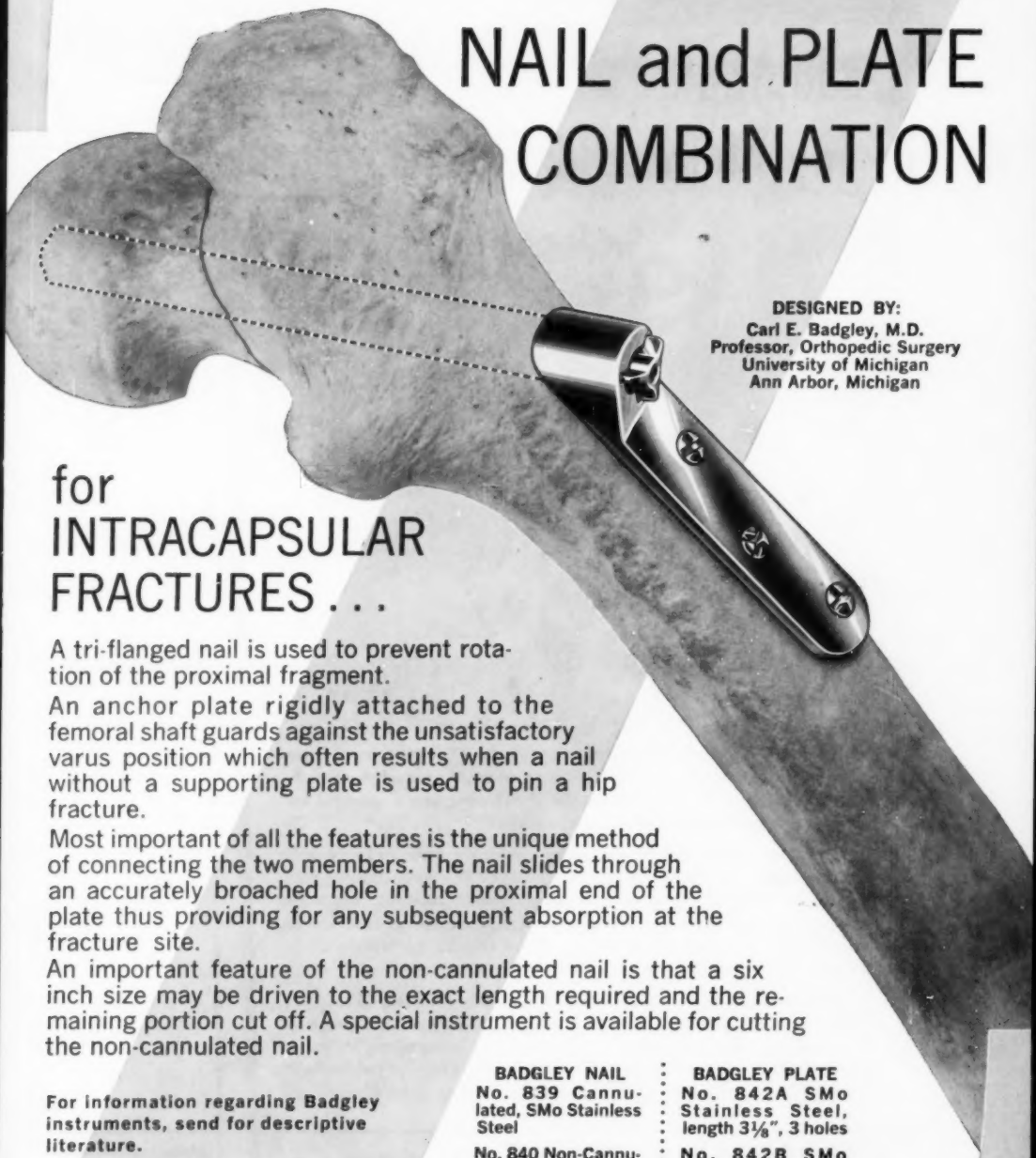

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Carl E. Badgley, M.D.
Professor, Orthopedic Surgery
University of Michigan
Ann Arbor, Michigan

for INTRACAPSULAR FRACTURES . . .

A tri-flanged nail is used to prevent rotation of the proximal fragment.

An anchor plate rigidly attached to the femoral shaft guards against the unsatisfactory varus position which often results when a nail without a supporting plate is used to pin a hip fracture.

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For information regarding Badgley instruments, send for descriptive literature.

BADGLEY NAIL	BADGLEY PLATE
No. 839 Cannulated, SMo Stainless Steel	No. 842A SMo Stainless Steel, length 3⅛", 3 holes
No. 840 Non-Cannulated, SMo Stainless Steel	No. 842B SMo Stainless Steel, length 4⅝", 5 holes

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SHOES

adaptable
in any of these directions.

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"...17 of...20 patients with post-traumatic muscle spasm of the low back had excellent or good responses."[2]

"In acute and chronic recurrent low back syndrome, seven of eight patients showed visible objective improvement."[3]

Bibliography

(1) Johnson, H. J., Jr.: To be published. (2) Wallace, S. L.: To be published. (3) Settel, E.: Am. Pract. & Digest Treat. 8:443, 1957.

How Supplied

Pink, Enteric Coated tablets (250 mg.), bottles of 36.
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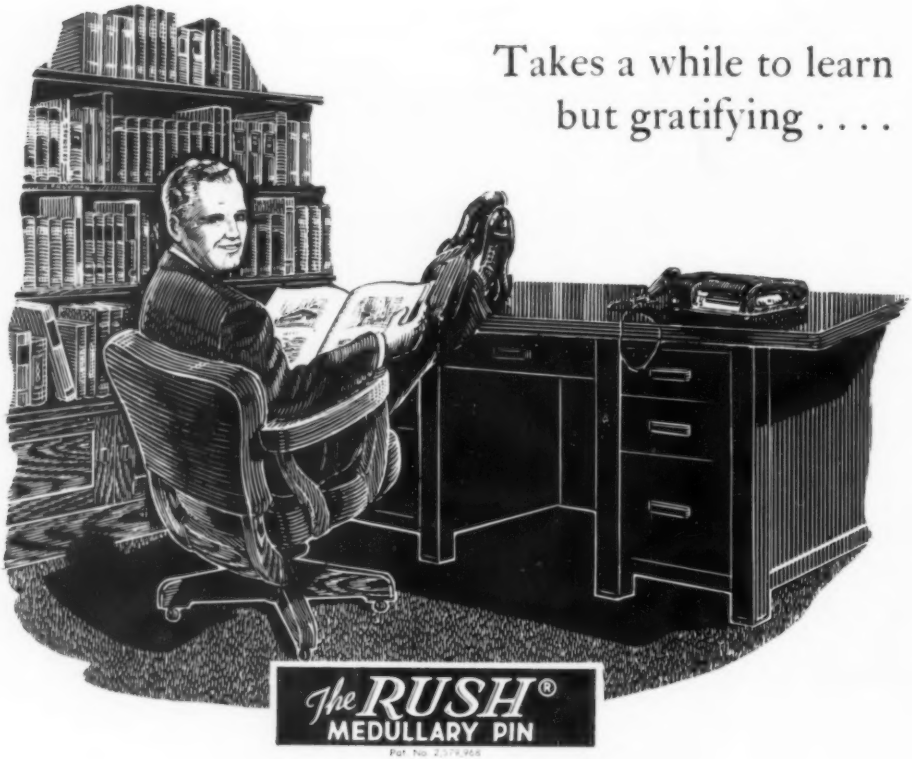

Proper application of the RUSH PIN is not always easy. It takes a while to learn. It is quite different in principle and technic from other forms of medullary fixation. It is not designed to impact the marrow cavity, but to accurately transfix the fractured bone by points of pressure, precisely applied.

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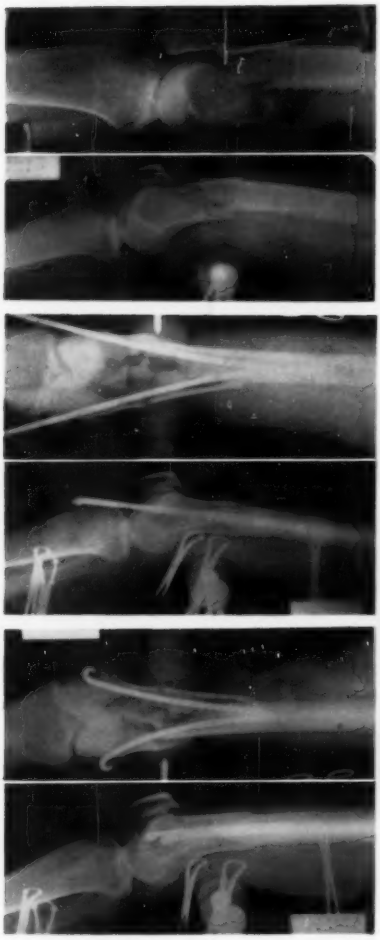

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PAT. No. 2,579,968

FOR FRACTURES OF FEMUR
AND TIBIA SHAFTS

Simplifies Pinning By:

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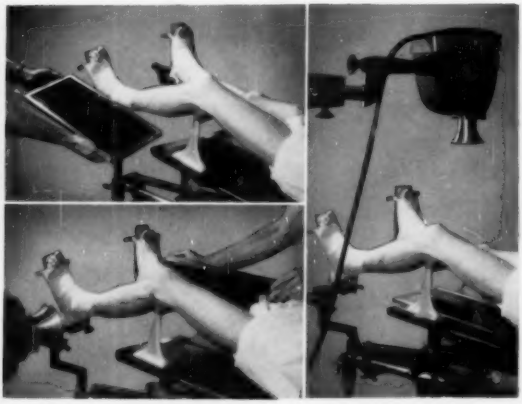
- ELEVATING LOWER FRAGMENT
- ALLOWING STERILE FIELD
- PERMITTING X-RAYS DURING PROCEDURE



X-Rays shown are actual operating room films showing technic of CLOSED PINNING of comminuted supra-condylar fracture of femur in elderly female. Note shadow of RUSH COUNTERSUPPORT.

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In addition to its spasmolytic effect, Disipal evokes a mildly euphoric response, particularly valuable in the Parkinsonian patient.

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Tibial Nail diameters: 5/16" and 3/8"

18-8 SMo Stainless Steel nail made in ½ inch lengths from 9 to 14½ inches.

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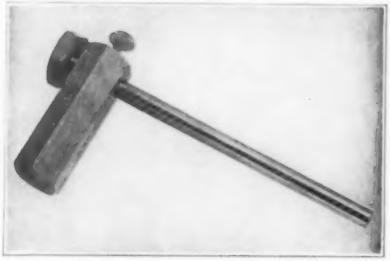

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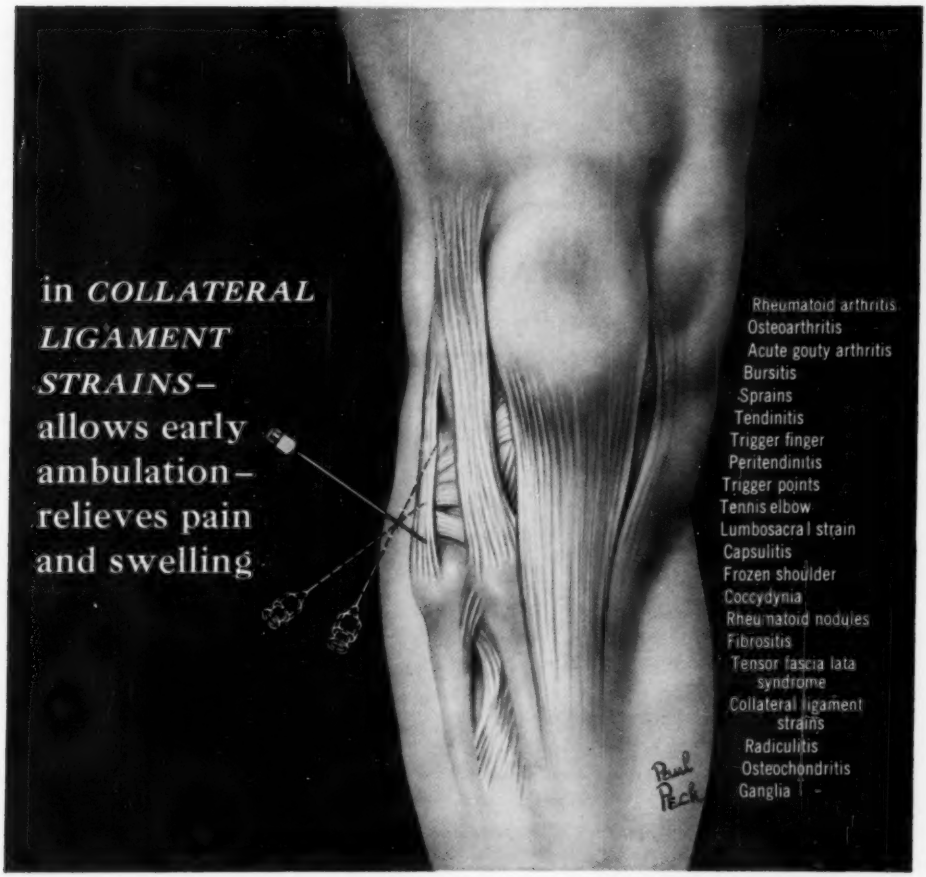
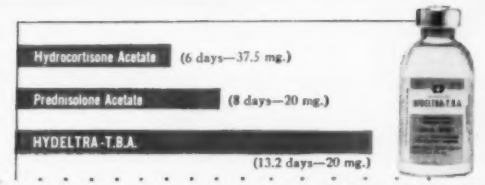
(Prednisolone *tertiary*-butylacetate, Merck)

for relief that lasts—longer



Duration of relief exceeds that provided by any other steroid ester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HYDELTRA-T.B.A.
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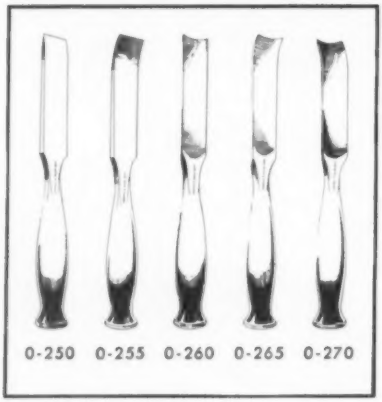

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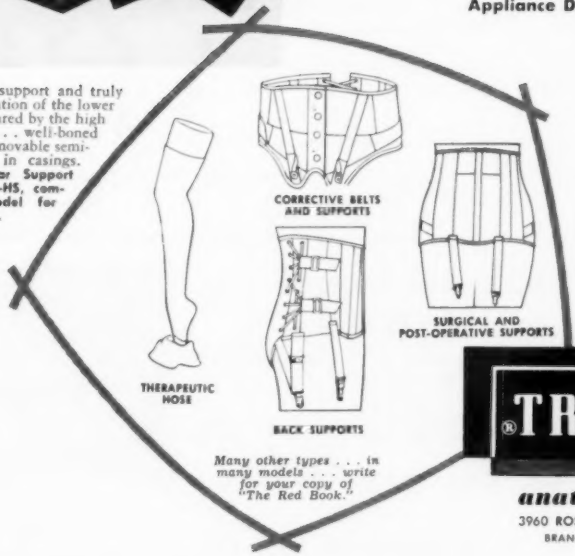

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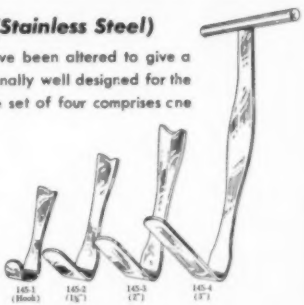

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*Reifenstein, E. C., Jr., in Harrison, T. R.: Principles of Internal Medicine, ed. 2, New York, The Blakiston Company, Inc., 1954, chap. 98, pp. 702, 703.

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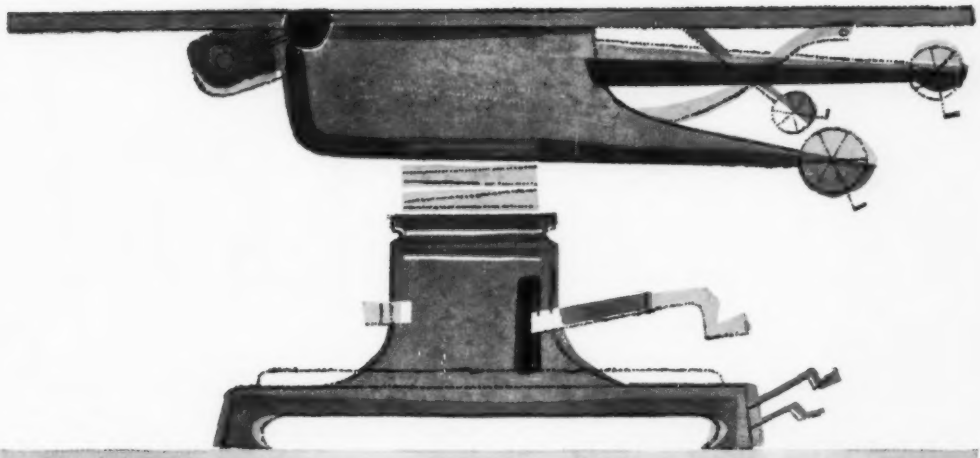
SteriSharps... the first sterile, stainless-steel surgical blade

do you have an overweight patient?



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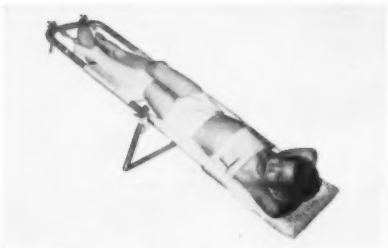

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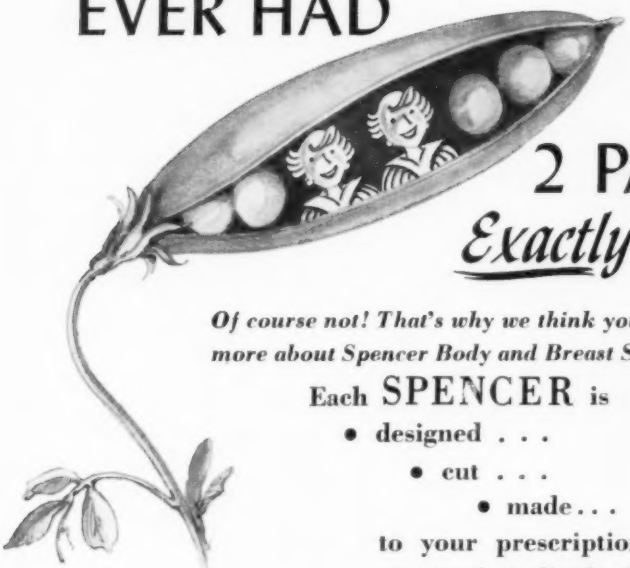

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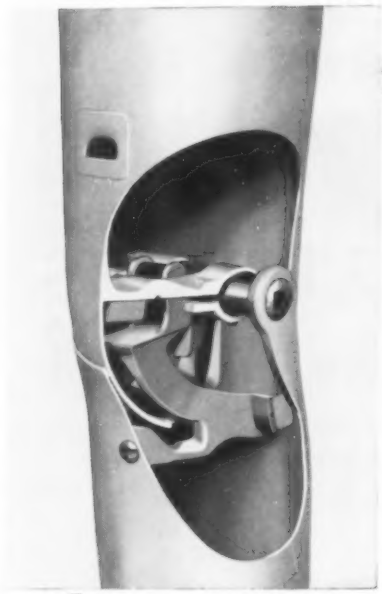

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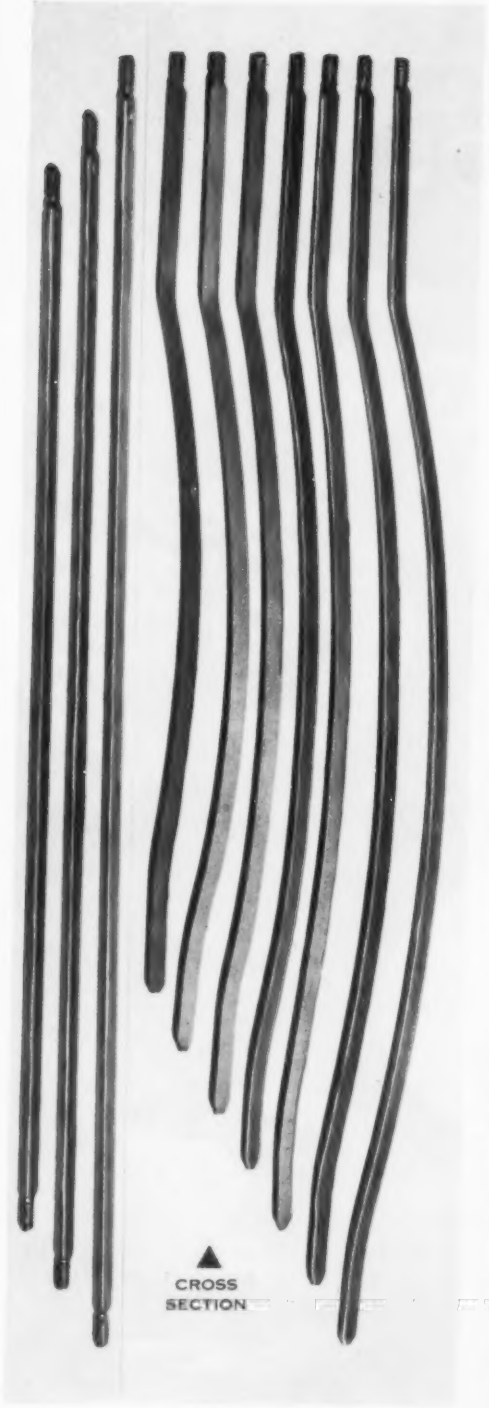

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The Journal of
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Spine Fusion in Young Children

A Long-term End-result Study with Particular Reference to Growth Effects*

BY HALFORD HALLOCK, M.D., KENNETH C. FRANCIS, M.D., AND JAMES B. JONES, M.D.,
NEW YORK, N. Y.

When posterior spine fusion is performed in the young child, the question often is raised as to what happens to the growth of the fused vertebrae. Do the vertebral bodies increase in height? Does the fusion plate or graft grow, or is an imbalance of growth produced which eventually would result in lordotic deformity?

Haas, Bisgard and Musselman showed in animals that longitudinal growth of the vertebral bodies takes place in the epiphyses much as it does in the long bones and that epiphyseal injury causes cessation of longitudinal growth. Haas demonstrated that fusion of the spinous processes imposed a retarding effect upon the development of the bodies; Bisgard and Musselman showed that fusion of vertebral bodies themselves with no damage to the epiphyseal cartilages *per se* did not arrest growth and that grafted bone under the influence of a distracting force was capable of intrinsic growth in length.

In order to answer these questions in man, a clinical and roentgenographic study was made of the growth effects of spine fusion in fifteen patients who had been operated upon in early childhood and who had been followed well into adolescence or adult life. In these cases early as well as end-result roentgenograms were available for measurements of the fused and contiguous unfused areas.

The operations were all done at the New York Orthopaedic Hospital, for tuberculosis; a Hibbs type of fusion was performed in each.

At that time, in order to be certain of immobilization of the entire area of disease, it was customary to include in the fusion at least two normal vertebrae above and below the diseased vertebrae as seen roentgenographically. This fact made it possible not only to study the growth effects of fusion upon diseased segments but also upon normal vertebrae.

The fusion areas in these patients involved the following regions of the spine: thoracic in seven, thoracolumbar in five, and lumbar in three. Tuberculosis involved two vertebrae in five patients, three in five, four in four, and five in one. The length of the fusion area ranged from twelve vertebrae in one patient, nine in three, eight in three, seven in four, six in three to five in one.

The degree of kyphosis varied from minimal in two patients to moderate or moderately severe in the rest.

Six of the patients were boys and ten were girls.

The youngest age at follow-up examination was fifteen years and the oldest was thirty-five, the average being twenty-four years. The shortest postoperative period of

* Read at the Annual Meeting of The American Orthopaedic Association, Banff, Alberta, Canada, June 21, 1956.

follow-up was twelve years and the longest was thirty-one years, the average being twenty-one years.

In all patients fusion was successful and the disease healed; no essential increase in deformity occurred in any of the patients after the first twelve or eighteen months following operation. For this reason, early postoperative rather than preoperative roentgenograms were measured. In most patients with tuberculosis some increase in kyphosis is the rule during the early postoperative period.

The measurements were made directly on lateral roentgenograms, care being taken to use comparable points on the early and late roentgenograms. Whenever possible, the following portions were measured: the entire fused area, two normal-appearing vertebrae

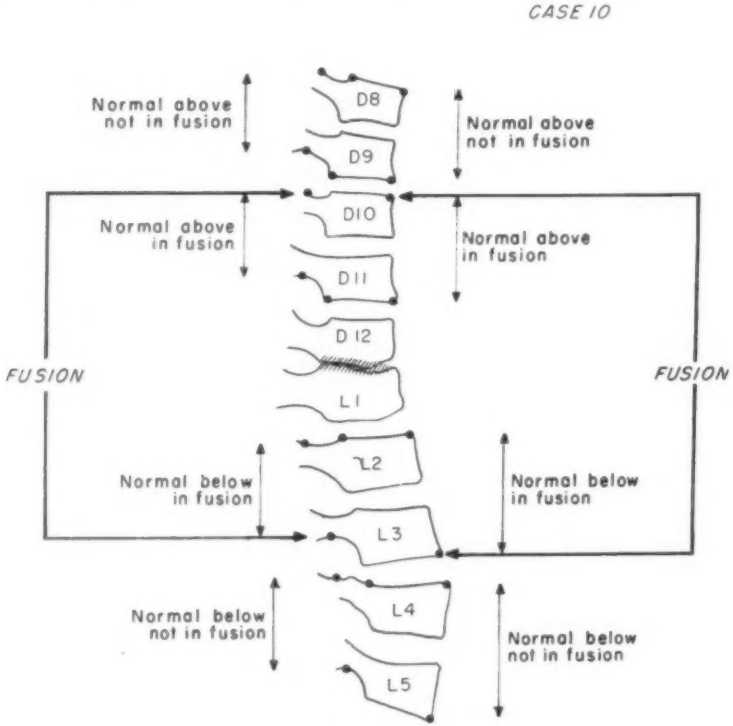


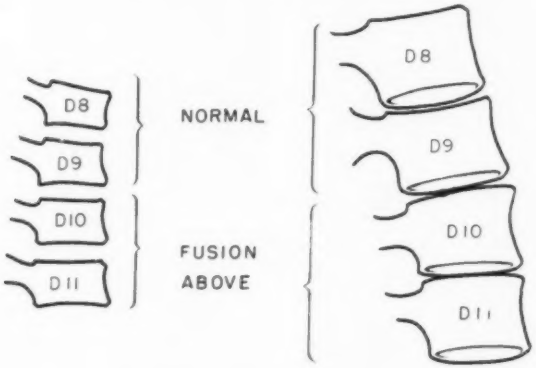
FIG. 1

Diagrammatic illustration of the method of measurement.

included in the fusion above and below the diseased area, and two or three normal contiguous vertebrae above and below the fusion. Disc spaces were included, and the measurements were of vertebral segments rather than of individual vertebrae. The calculated mean between the values for the anterior and posterior vertebral borders was used to express the length or height of any vertebral segment.

It was impossible in most instances to measure accurately the posterior fusion plate because of overlying bone shadows and uncertainty as to the exact upper and lower limits of the fusion mass. The best that could be done was to measure comparable points on the adjacent upper and lower pedicles as these were generally well delineated. Undoubtedly, they are subject, as well as the laminae, to the laws governing interstitial or intrinsic growth. It is believed, therefore, that measurements of this area probably provide a representative picture of the growth changes actually occurring in the fusion plate (Fig. 1).

When sizes of early and late x-ray images were compared, in order to eliminate the effects of unknown earlier target-to-tube distance and of greater target-to-spine distance, later on, subsequent to patient's growth in thickness, it was necessary to compare the end result with the original measurements in terms of percentage increase over 100. This method was suggested by Albert Ferguson as a valid means of determining under these circumstances the growth changes in these patients as seen in the roentgenograms. For example, if a fusion area measures ten centimeters in length in the original roentgenogram and fifteen centimeters in the end-result roentgenogram, the percentage change equals 150 divided by 100 which is 1.5 or an increase of 50 per cent. If the contiguous segment of the normal spine increases from twelve to twenty-four centimeters, the change is 2 or



CASE 10

BODIES

NORMAL	MEAN PRE-OP = 3.05cms MEAN POST-OP = 5.65cms	190% OR 90% CHANGE
FUSION	MEAN PRE-OP = 3.35cms MEAN POST-OP = 5.25cms	160% OR 60% CHANGE

RESULT – 30% LESS GROWTH IN FUSION AREA

POSTERIOR ELEMENTS

NORMAL	PRE-OP = 2.4 cms POST-OP = 4.1 cms	170% OR 70% CHANGE
FUSION	PRE-OP = 2.8 cms POST-OP = 3.4 cms	120% OR 20% CHANGE

RESULT – 50% LESS GROWTH IN FUSION AREA

FIG. 2

Method of comparative measurement on the basis of percentage increase over 100. The figures given were obtained from Case 10.

a gain of 100 per cent. The fusion area, therefore, grew 50 per cent less than the normal spine (Fig. 2).

An example of the percentage measurements as obtained and plotted from the roentgenograms of one patient is shown in Chart I.

Four changes were apparent in the roentgenograms of these patients:

1. Once the area of disease had become stabilized following fusion, there was little or no further change in the kyphos. The roentgenograms of one patient, however, showed an actual decrease in the kyphos, due apparently to the regrowth of bone in a previously half-destroyed vertebral body. Clinically, however, some patients, at follow-up examina-

tion, appeared to have a less prominent or conspicuous kyphos than before. This seemed to be due to the development of a compensatory lordosis above and below the fusion. For the most part, this occurred in the normal unfused spine; but in three patients, some lordosis took place also in those portions of the fusion consisting of included normal vertebrae. Posterior wedging of the vertebrae was seen in both areas; and as comparative measurements revealed that fusion had only a slightly greater retarding effect on the growth of the posterior elements than on the bodies, it is probable that this change occurred chiefly as the result of a molding and a compensating process subsequent to the action of the righting reflex in preserving an erect attitude. In one child, however, considerable lordosis occurred just above a kyphos in a segment of three fused normal vertebrae

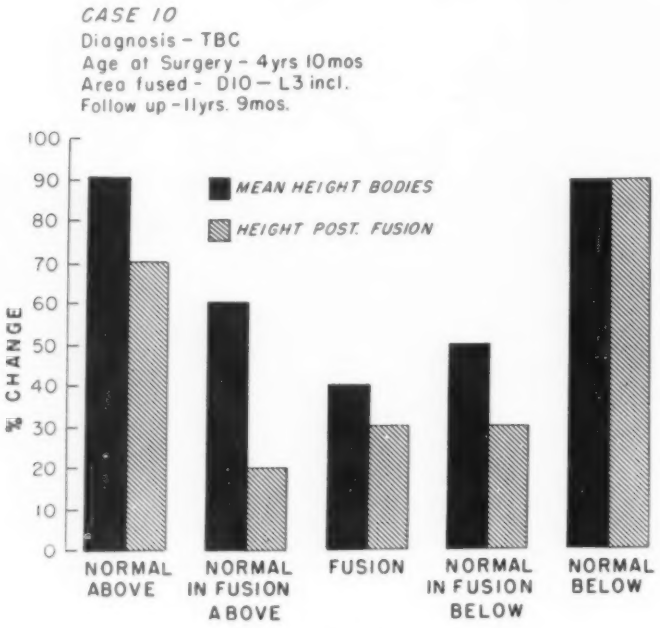


CHART I
Measurements in Case 10.

in which the posterior portions of the disc spaces had become almost completely obliterated. This suggests, at least in this case, the additional action of a definite growth imbalance.

2. Narrowing of the intervertebral spaces in the fused area occurred in all patients. Except when the discs had been completely destroyed by the disease process, this phenomenon was seen in all areas of a fusion. In four patients actual obliteration of part of a disc occurred, usually posteriorly, in normal portions of a fusion area. This change in the discs may be the result of disuse atrophy following immobilization of the vertebrae or of the effect of increasing pressure imposed upon the discs by posterior laminar fusion in the presence of growth potential in the cartilaginous plates of the vertebral bodies. Both mechanisms probably play a part.

3. It was curious to see consistently a trapeziform development of the last normal vertebral body at the end of a fusion area. That portion distal to the arthrodesis appeared to have developed much more than the proximal half, resulting in an increase in both the anteroposterior and lateral diameters and in an approximation of this portion of the body

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 10, C. K. Early postoperative roentgenogram. Fusion had been done from the tenth thoracic to the third lumbar vertebra for tuberculosis at age five.

Fig. 3-B: End-result lateral roentgenogram made twelve years later when the patient was seventeen. Note the lack of change in the kyphos at the twelfth thoracic and first lumbar vertebrae, the narrowing of the intervertebral spaces in the fused area, the trapeziform development of the end-vertebrae in the fusion, and the underdevelopment of the vertebral bodies in both planes in the area of fusion.

to the size of the contiguous unfused vertebra. This indicates a definite retarding effect upon the development of the proximal portion of a fused end-vertebra.

4. In all of the patients underdevelopment was noted in the fused vertebral bodies. This was recognized as a diminution in both the sagittal and transverse diameters. In the areas of previous disease, the change was more pronounced, undoubtedly because of destruction of bone and cartilage by the original tuberculous infection (Figs. 3-A through 4-B).

RESULTS OF MENSURATION

The measurements expressed in comparative percentage change revealed that in these patients growth continued in the fused area but to a lesser degree than in the contiguous normal and unfused vertebrae. Retardation of growth occurred in the vertebral bodies and to a somewhat greater degree in the posterior elements; this took place in both the old diseased areas and in the normal portions included in the fusion. Considerable individual variation of growth occurred, even in those patients who were of similar age when operated upon; but, as was to be expected, the total amount of growth was greater in those who were younger at the time of operation (Chart II).

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 7, M. L. L. Fusion of the eleventh thoracic to the third lumbar vertebra was done for tuberculosis at age three. Two years later the tenth thoracic and the fourth lumbar vertebrae were included in the fusion. This anteroposterior roentgenogram was made twenty-two years after the first operation when the patient was twenty-five. The developmental changes are the same as those observed in Case 10.

Fig. 4-B: Lateral roentgenogram made twenty-two years after the first operation.

The following averages were derived from fifteen of the patients, in each of whom it was possible to measure all three areas: the entire fusion, fused normal vertebrae, and contiguous unfused normal vertebrae either above or below the area of old disease.

The average growth anteriorly in the fusion area as a whole was 36 per cent less than that in the normal spine above; the average growth in the posterior elements was 47 per cent less. Compared with the normal vertebrae below, growth was 39 per cent less anteriorly and 43 per cent less posteriorly. When these values were combined, the result showed that growth in the entire fusion area was 37 per cent less anteriorly and 45 per cent less in the posterior elements (Chart III).

Of greater interest in regard to the effects of arthrodesis upon growth was the behavior of the normal vertebrae that had been included in the fusion above and below the areas of disease. The percentage measurements of normal segments and fused normal segments above the area of disease in ten patients are shown in Charts IV-A and IV-B; the percentage measurements of normal segments and fused normal segments below the zone of infection in ten patients are shown in Charts V-A and V-B.

On an average, the fused normal vertebrae above the diseased area grew 26 per cent less anteriorly and 38 per cent less in the posterior elements than the normal unfused vertebrae just above. Below the area of infection, the fused normal vertebrae grew 20 per cent less anteriorly and 33 per cent less posteriorly than the normal vertebrae just below.

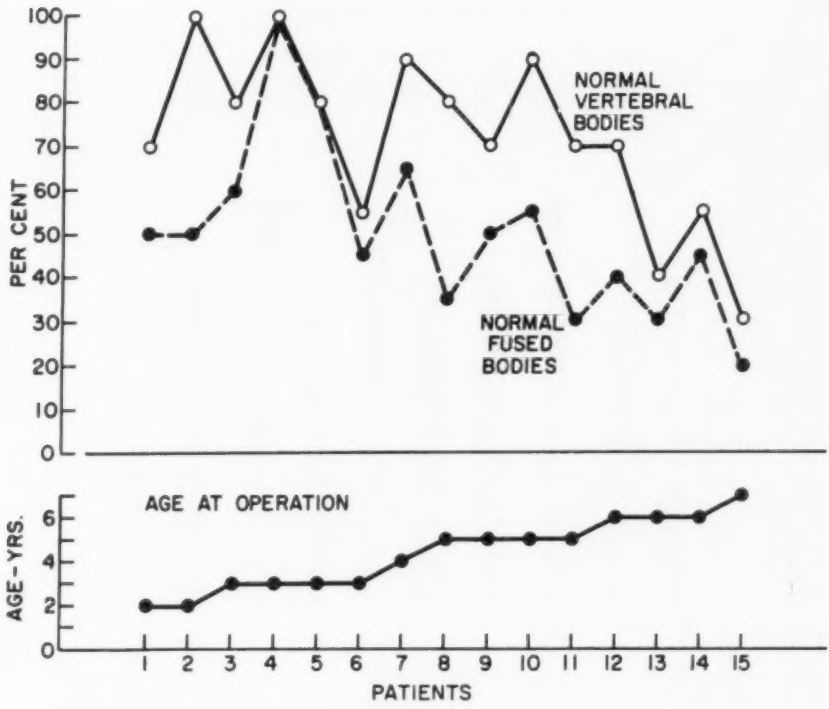


CHART II

Effect on growth of age at the time of fusion expressed in percentage increase in length of the fused segment. Note the considerable individual variation in growth even in those patients who were about the same age at the time of operation. Note also the greater total amount of growth in those who were younger when operated upon.

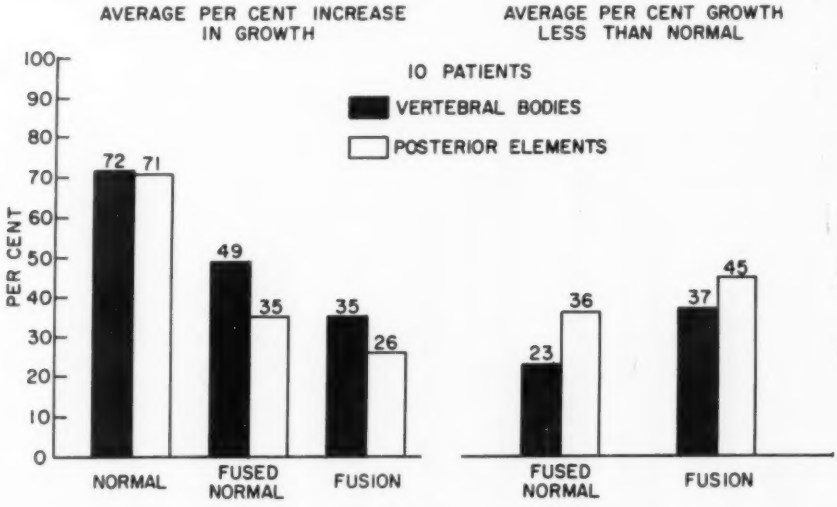


CHART III

Average percentage of growth in normal fused vertebrae and in the fusion areas (left). Average percentage loss of growth in relation to the normal in fused normal vertebral segments and in the whole fusion area (right).

VERTEBRAL BODIES

NORMAL ABOVE FUSION:
NORMAL IN FUSION ABOVE DISEASED AREA

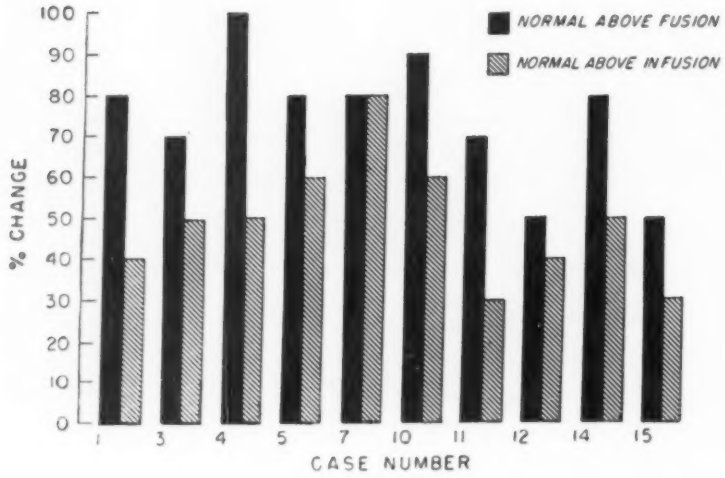


CHART IV-A

Charts IV-A and IV-B: These charts show individual percentage growth of the vertebral bodies and posterior elements in normal and fused normal segments in ten patients. The segments were above the area of disease.

POSTERIOR ELEMENTS

NORMAL ABOVE FUSION:
NORMAL IN FUSION ABOVE DISEASED AREA

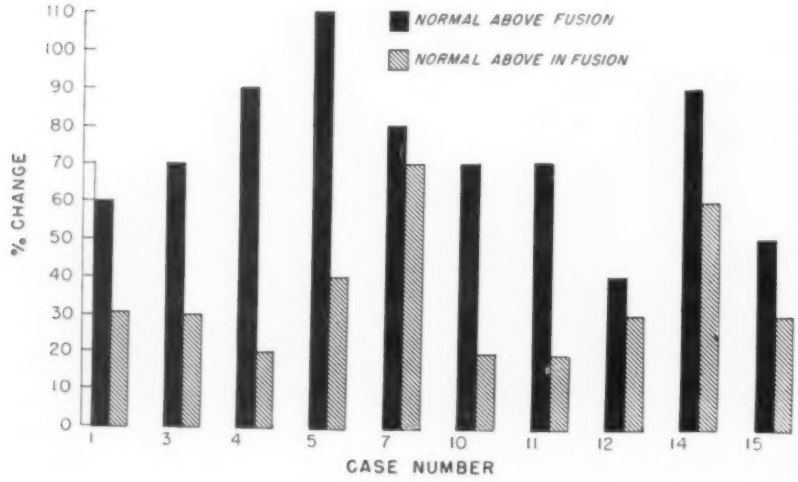


CHART IV-B

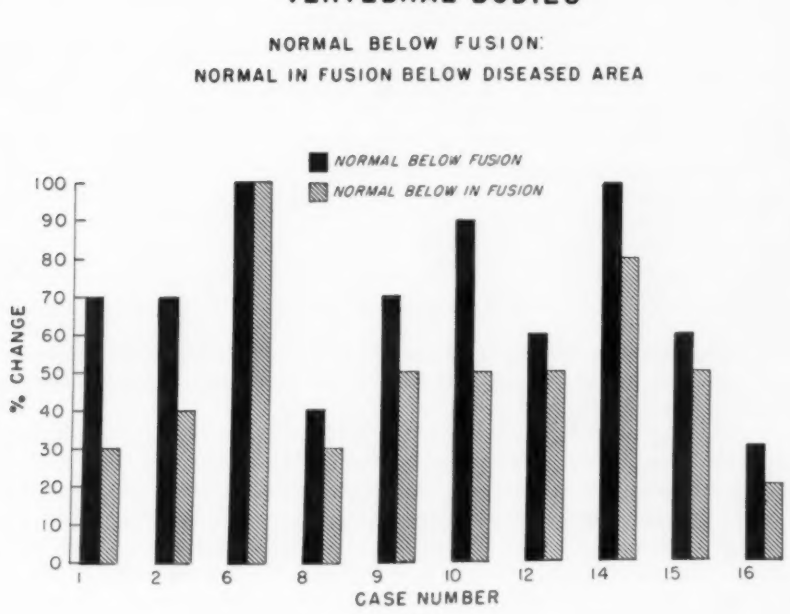


CHART V-A

Charts V-A and V-B: The charts show individual percentage growth of the vertebral bodies and posterior elements in normal and fused normal segments in ten patients. The segments were below the area of disease.

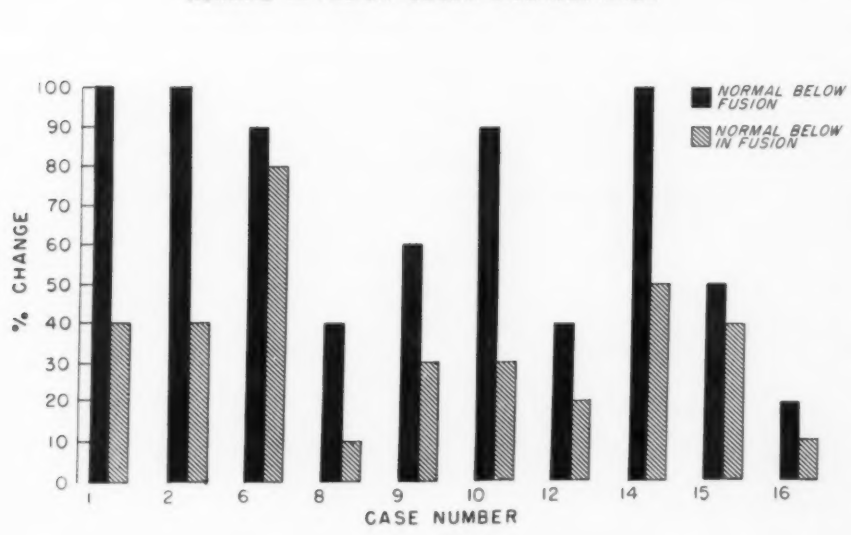


CHART V-B

TABLE I

PRESACRAL TRUNK MEASUREMENTS (PIERSOL)

	Neck (*Centimeters*)	Back (*Centimeters*)	Loins (*Centimeters*)	Total (*Centimeters*)
Average in fifty adult men (Dwight)	13.3	28.7	19.9	61.9
Average in four boys one year of age (Dwight, one; Chipault, three)	6.4	12.3	7.8	26.5
Average in two boys five years of age (Symington, one; Ravenel, one)	8.0	17.5	12.0	37.5
Growth (calculated) after one year	6.9	16.4	12.1	35.4
Growth (calculated) after five years	5.3	11.2	7.9	24.4

When these figures were combined, it was seen that the average growth in the fused normal vertebral segments was 23 per cent less anteriorly and 36 per cent less in the posterior elements than in the normal unfused spine (Chart III).

In Table I is given the average length of the different presacral regions, including the intervertebral discs, measured along the anterior surface of the spine in fifty adult men (Dwight), the average measurements in four boys approximately one year of age (Dwight, 1; Chipault, 3), and in two boys five years of age (Symington, 1; Ravenel, 1) reported in the Ninth Edition of Piersol's *Human Anatomy*. From these figures have been calculated the average amounts of presacral trunk growth to be expected after one and five years of age in the cervical, thoracic, and lumbar regions of the spine. These values are 6.9, 16.4, and 12.1 centimeters, respectively, for these areas at age one; and 5.3, 11.2, and 7.9 centimeters at age five. No distinction in the relative length or growth could be made between the upper and lower portions of the thoracic spine from the data available.

The calculated loss of growth resulting from 25 and 40 per cent retardation by areas of fusion at one and five years of age in the thoracic and lumbar regions of the spine is given in Table II. From this, it can be seen that fusion of the whole thoracic spine at age one should decrease ultimate presacral stature by only 3.8 centimeters with 25 per cent reduction or 6.1 centimeters with 40 per cent reduction; and of the whole lumbar spine by only 3.3 centimeters with 25 per cent or five centimeters with 40 per cent reduction. With fusion at five years of age, the loss would be even less than this.

COMMENTS

The data obtained in these fifteen patients, when related to the calculated growth in

TABLE II

CALCULATED LOSS OF PRESACRAL GROWTH FOLLOWING FUSION

	Six Thoracic Vertebrae (*Centimeters*)	Twelve Thoracic Vertebrae (*Centimeters*)	Five Lumbar Vertebrae (*Centimeters*)
Growth potential at one year of age (Table I)	8.2	16.4	12.1
At five years of age	5.6	11.2	7.9
Growth loss resulting from 25 per cent retardation following fusion at one year of age	2.1	4.1	3.0
At five years of age	1.4	2.8	2.0
Growth loss resulting from 40 per cent retardation following fusion at one year of age	3.3	6.6	4.8
At five years of age	2.2	4.5	3.2

the different presacral regions of the spine at one and five years of age, would indicate that on the average fusion at an early age will not diminish ultimate stature to any marked degree as growth in fused normal segments was only 23 per cent less than in adjacent normal unfused vertebrae. However, when the factors of vertebral-body destruction from disease and consequent inhibition or cessation of growth were present in addition, the average loss of growth was greater—37 per cent. This has been borne out clinically as these children have not developed into unduly short persons over and above what could have been expected from the ravages of the disease itself. This confirms the conviction that in tuberculosis fusion should be done early before major vertebral destruction and deformity have occurred.

As growth of the posterior elements of fused normal vertebrae averaged only 13 per cent less than that in adjacent normal segments, it would seem that there would be little prospect of producing significant lordotic deformity by fusion in childhood; or conversely, little hope of achieving by this means any major correction in dorsal round-back, unless the fusion were performed at a very early age and over an extensive area.

SUMMARY

The growth effects of spine fusion in early childhood were observed and measured roentgenographically in fifteen patients who were operated upon for tuberculosis and who were followed into adolescence and adult life. In all fusion was successful and the disease of the spine healed; and, since in all of them at least two normal vertebrae had been included in the fusion above and below the diseased area, an unique opportunity was offered to study the effects of arthrodesis on growth in fused normal vertebrae as well as in diseased vertebrae.

The growth changes observed were narrowing of the intervertebral disc spaces in the fusion area with occasional partial obliteration, a trapeziform development of the end-vertebrae, and underdevelopment of the fused vertebral bodies in both the sagittal and frontal planes.

Whenever possible, measurements were made from early postoperative and end-result lateral roentgenograms of the entire fusion area, the normal vertebrae that were included in the arthrodesis above and below the disease, and the normal contiguous spine segments. In order to eliminate the error of unknown early target-to-tube distance and an increase in the target-to-spine distance caused by growth in thickness of the patient, the measurements were expressed and compared as percentage change over 100.

In fifteen of the patients, in each of whom it was possible to measure the entire fusion area, fused normal vertebral segments and normal vertebral segments either above or below the old diseased area, or both, it was found that considerable variation of growth occurred even in individuals of similar age at operation. On an average, the entire fusion area grew anteriorly 37 per cent less and posteriorly 45 per cent less than normal vertebrae. The fused normal vertebrae grew 23 per cent less anteriorly and 36 per cent less in the posterior elements than adjacent normal unfused vertebrae.

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Observations on the Value of Clinical Electromyography

BY BENJAMIN L. CRUE, M.D., ROBERT H. PUDENZ, M.D., AND C. HUNTER SHELDEN, M.D.,
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Electromyography is an important aid in modern neurosurgical, orthopaedic, and neurological practice. With the development of a practical cathode-ray oscilloscope electromyograph in which a needle electrode is used, the clinician has been presented with a reliable investigative technique which is sensitive far beyond his own powers of observation [5]. It must be repeatedly pointed out that there can be no comparison between this technique and the older less sensitive methods in which either skin electrodes or an ink recording is used. Although much has been written concerning the role of electromyography in investigative research [3, 4], too little emphasis has been placed upon its diagnostic value to the busy practitioner [6, 7, 8].

UNDERLYING PRINCIPLES AND TECHNIQUES

Normal muscle at rest is electrically silent. Normal muscle, upon voluntary contraction, demonstrates a series of typical normal biphasic waves of a magnitude from 100 to 3,000 microvolts and a duration of two to ten milliseconds. This represents the firing of a single anterior horn motor neuron and the subsequent orderly contraction of many individual muscle fibers under the control of a single axon. The number of muscle fibers varies tremendously according to the muscle, apparently having a ratio of almost one to one in the extra-ocular muscles. In the large skeletal muscles, each neuron may control over 100 such muscle fibers. This is the functional equivalent of the anatomical entity known as the motor unit of the final common motor pathway. It must be emphasized that, electromyographically, we are measuring not the electrical activity coming down the axon but the electrical current produced by the contracting muscle fibers themselves.

In the human being, when a muscle is denervated by interruption anywhere along the lower motor neuron from the anterior horn cell to the motor end-plate for any reason whatsoever, the individual motor fibers begin an involuntary contraction of their own after approximately twenty-one days. This contraction of the muscle fiber is known as *denervation fibrillation* and is not clinically discernible by the human eye except in the tongue. This contraction must be carefully distinguished from the abnormal involuntary discharge of a motor horn cell producing a contraction of many muscle fibers, noticeable clinically as a twitching of the muscle and termed *fasciculation*.

The electrical activity of the contracting single muscle fibers during denervation fibrillation can be picked up by either monopolar or bipolar needle electrodes and seen on a cathode-ray tube. This activity is much smaller than that of the motor unit, being from ten to 100 microvolts in amplitude, and lasts a much shorter time, having a duration of one to two milliseconds. It is no wonder that these electrical impulses are often missed on an ink-writing apparatus or by the use of skin electrodes.

There are many abnormalities of the lower motor neuron which may be distinguished by electromyography. Myotonia gives a characteristic wave. The voluntary motor unit is often complex and bizarre, apparently when conduction is abnormal, as may be seen in such diseases of the anterior horn cell as progressive spinal muscle atrophy and pathological conditions of the axon such as peripheral neuritis. It is, however, the finding of denervation fibrillation which leads to a positive diagnosis in most of the syndromes of orthopaedic and neurosurgical interest, including the nerve-root compression syndrome.

Thus, in suspected disc disease, even though there may be unsustained electrical abnormality and electrical hyperirritability, a positive report is not given unless definite denervation fibrillation is found. This may lead to a larger percentage of false negatives, but one can state dogmatically—as much as one can ever be dogmatic in medicine—that one of the chief values of electromyography is that there should be no false positives. Occasionally, however, there will be wrong interpretations of positive findings, as will be discussed later.

It should be pointed out that a thorough knowledge of the peripheral nerves and the nerve roots is needed. A valid generalization regarding radicular distribution is that all skeletal muscles receive fibers from more than one root and that all roots run to more than one muscle. This knowledge is of use in localization.

In a suspected lumbar-disc disease, if denervation fibrillation is found in the tibialis anterior muscle (supplied by the fourth and fifth lumbar-nerve roots), and in the peroneals (the fifth lumbar and first sacral-nerve roots), but not in the quadriceps (the second, third, and fourth lumbar-nerve roots), or in the medial head of the gastrocnemius (the first and second sacral-nerve roots), and if the condition is a nerve-root lesion, localization of the lesion should be at the fifth lumbar-nerve root. However, it must be remembered that the lesion could be the result of an old injury of the peroneal nerve, and therefore, denervation fibrillation may also be looked for in the sacrospinalis muscle which is supplied by the posterior primary division of the fifth lumbar-nerve root. It must also be remembered that a pathological condition involving the fifth lumbar-nerve root does not necessarily indicate compression by disc protrusion, but may be caused by tumor. If the condition under examination is due to herniated disc, there is only a high probability that the lesion is at the fourth and fifth lumbar vertebral level.

The technique of electromyography can be described in a few words. The patient is examined when he is fully awake and usually without sedation. The needle electrodes are uncomfortable but are easily tolerated by the majority of patients. A ground plate is fastened to the skin of the extremity to be tested, and electrical contact is assured by the use of electrode paste. Each muscle to be tested is examined in at least two areas. A sterile needle, completely insulated except at the tip, is introduced through the skin, which causes the most discomfort, and is then successively inserted to four different depths in five directions. In this way at least forty different areas are examined in each tested muscle before the result may be considered negative. Such a thorough search is mandatory, especially in nerve-root compression syndromes in which the degree of denervation fibrillation may be minimal. While this search is being made, the needle electrode is connected to a cathode-ray oscilloscope and to a loudspeaker. The waves can thus be seen and heard. The result is usually reported directly, but the waves may be photographed or they may be recorded on magnetic tape and played back later, to be heard, seen, and photographed at another time, to be used for teaching purposes, or for legal testimony.

HERNIATED LUMBAR INTERVERTEBRAL DISC

Perhaps the most frequent utilization of electromyography at the present time is in the syndrome of herniated lumbar intervertebral disc [9, 10]. Here its accuracy compares well with pantopaque myelography [1] and clinical localization. Electromyography is simpler than myelography as a preliminary screening test.

During the three-year period, 1951 to 1954, there were recorded 136 consecutive cases of herniated nucleus pulposus at the fourth to fifth lumbar interspace and the fifth lumbar to the first sacral interspace when both electromyography and myelography had been done preoperatively. These were all verified by laminectomy (Table I). At the fourth to fifth lumbar disc level, where the dural canal widens, the myelogram was more reliable. When the herniation was at the fifth lumbar, first sacral level, the electromyogram was slightly superior to the myelogram in accuracy.

TABLE I

HERNIATION OF THE NUCLEUS PULPOSUS OF THE FOURTH TO FIFTH LUMBAR AND THE FIFTH LUMBAR TO FIRST SACRAL INTERVERTEBRAL SPACES—136 CASES VERIFIED BY LAMINECTOMY

Fifth lumbar to first sacral intervertebral discs (eighty-six cases)	Large Extrusion or Protrusion (68 cases)		Small Protrusion (18 cases)	
	(No. Correct Localizations)	*(Per cent)*	*(No. Correct Localizations)*	*(Per cent)*
Clinical localization of level	57	84	15	83
Electromyogram localization	56	82	14	77
Myelogram localization	53	78	12	67
Fourth to fifth lumbar intervertebral disc (fifty cases)	(34 cases)		(16 cases)	
Clinical localization of level	22	65	7	44
Electromyogram localization	23	68	6	37
Myelogram localization	30	88	13	81

There are at least three reasons why, with our present knowledge, it is doubtful if the accuracy of the electromyogram in this syndrome can be significantly improved:

1. After nerve damage, approximately twenty-one days must elapse before the degenerative process manifests itself by electrical changes in the muscle other than by a loss in activity of the normal voluntary motor units. While the changes shown in a time sequence of electromyographic serial studies are often of extreme importance, this initial delay is a definite handicap in the nerve-root compression syndrome. In acute severe intervertebral disc herniations it is often impossible to wait three weeks before instituting treatment.

2. Sometimes a patient is seen who apparently has a large disc protrusion with severe pain caused by compression or irritation of the posterior sensory-root component, the anterior motor nerve root being spared. This condition produces a false negative electromyogram, since at present the electromyogram reports only changes due to damage to the motor fibers.

3. Interpretation of a specific nerve-root lesion to mean a specific disc level may lead to an occasional error. Usually a herniated disc at the fourth and fifth lumbar level compresses the fifth lumbar-nerve root, while a herniated disc at the fifth lumbar, first sacral level compresses the first sacral-nerve root. But a herniated disc at the mid-line fourth and fifth lumbar level may catch the first sacral-nerve root and spare the usually involved, more lateral fifth lumbar-nerve root. To interpret the first sacral-nerve root lesion, reported by electromyography, as an involvement at the fifth lumbar-first sacral disc level would lead to error. Here the myelogram would be the deciding agent.

However, there have been instances when the myelogram was negative and the clinical findings were questionable, but, on the basis of a positive electromyographic localization, the involved nerve root was explored and the disc protrusion was found. The important consideration is that clinical localization, myelography, and electromyography used separately are correct in only about two-thirds of the cases, but there is a greatly reduced chance of error when all three methods are used in combination. In 136 consecutive cases shown in Table I, a preoperative error in localization of the involved disc was made in only one instance. This is an accuracy of over 99 per cent. The utilization of all three methods of localization should preclude the surgical procedure of lumbar exploration with routine exposure at multiple levels.

(A more detailed study of the electromyogram in these and in subsequent herniated lumbar discs is planned for future publication. The clinical application of electromyography in the lumbar-disc syndrome will not be discussed further in this report.)

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Oblique cervical roentgenogram showing an osteophytic spur at the fourth to fifth cervical vertebral level.

Fig. 1-B: Myelogram showing a large defect at the seventh cervical, first thoracic level, and a small defect at the fourth to fifth cervical level. Both are on the right.

APPLICATION OF ELECTROMYOGRAPHY IN OTHER SYNDROMES

The electromyogram is of value in various other conditions, such as herniated cervical discs, plexus injuries, peripheral-nerve injuries, degenerative diseases of the spinal cord, and inflammatory diseases such as poliomyelitis. These applications have been well described by Woods and Shea. Rather than recapitulate, the authors wish to present a series of cases encountered over a two-year period (1953 to 1955) in order to illustrate the clinical usefulness of electromyography. It is believed that incorrect or insufficient treatment might have been given these patients, had it not been for the electromyogram.

The first case illustrates the usefulness of the electromyogram in the herniated cervical intervertebral disc.

CASE 1. A housewife, forty-two years old, was admitted to the hospital complaining of severe pain in the right side of the neck, the right shoulder, arm, and little finger of three weeks' duration. She reported that this pain had come on suddenly when she turned in bed. Neurological examination revealed a decreased right triceps reflex and hypo-algesia in the distribution of the eighth cervical nerve. A tentative diagnosis was made of acute herniation of the intervertebral disc between the seventh cervical and the first thoracic vertebrae, compressing the eighth cervical-nerve root. Roentgenograms of the cervical spine were made (Fig. 1-A). A cervical myelogram was made which revealed a large defect at the seventh cervical, first thoracic interspace on the right (Fig. 1-B). A routine preoperative electromyogram revealed not only minimal changes compatible with degeneration and demyelinization in the eighth cervical-nerve root distribution (all that could be expected with such a short history), but it also revealed notable changes in the distribution of the fifth cervical-nerve root on the right. Further questioning revealed that the patient had had an increasingly severe recurrent pain limited to the right shoulder and scapular area for at least two years. Review of the oblique cervical roentgenograms showed an osteophytic spur in the right fourth to fifth cervical foramina. The myelogram also showed an abnormal fifth cervical root cuff which had been overlooked. At laminectomy, a large, fresh extrusion between the seventh cervical and first thoracic vertebrae was removed as well as a typical "hard disc" at the fourth to fifth cervical level. In this patient an excellent result was obtained.

In retrospect we must admit that in this case an electromyogram should not have been necessary. A more complete initial history and a close scrutiny of the roentgenograms would have probably established the existence of two lesions. However, the patient's extreme pain made examination difficult and the large defect shown by myelography certainly focused attention at the seventh cervical, first thoracic level. Had it not been for the electromyogram, the patient would probably have continued to have symptoms after the operation from the overlooked lesion at the fourth to fifth cervical level.

Case 2. A woman, fifty-eight years old, was seen with the complaint of weakness and spasticity of both lower extremities. Previously, she had been extensively examined in a Midwestern university hospital. A cervical myelogram had been made. This revealed multiple disc protrusions in the cervical area, particularly severe at the fourth to fifth cervical and the fifth to sixth cervical interspaces. Cervical laminectomy had been advised. The patient refused surgery and went to California. On her admission to the hospital, neurological examination revealed that her feet and limbs were held in marked extension and were rigid. The deep tendon reflexes were hypo-active, but present. Babinski's sign was questionably present, bilaterally. There were no fasciculations. No sensory loss could be demonstrated. The patient was bedridden and unable to walk. General physical examination revealed the skin of the legs to be tan in color. The liver and spleen were enlarged. An electromyogram of the left lower extremity revealed lower motor neuron disease with extensive denervation voltages in all areas tested. Subsequent investigation led to the diagnosis of a primary xanthomatosis with involvement of the central nervous system. The patient was discharged to her home.

Case 3. A white woman, fifty-two years old, had partial quadriplegia when first seen. This condition had developed gradually over a period of several months. The patient was a Christian Scientist who had not been under a doctor's care. She cooperated poorly, and the diagnosis had to be established mainly by objective methods. The patient appeared to be in severe pain although she would admit none. Neurological examination disclosed a spotty sensory loss to pin prick on the trunk and the extremities. Sensation was completely normal above the eighth cervical-nerve level. The feet were held in plantar flexion and the lower extremities appeared spastic. Roentgenograms of the spine were negative. A lumbar puncture revealed an initial spinal-fluid pressure of 150 millimeters of fluid with normal dynamics. The spinal fluid contained eleven cells per cubic millimeter; Pandy test, ++++; and a total protein content of 210 milligrams per 100 cubic centimeters. Cervical myelography was interpreted as showing a questionable widening of the cervical enlargement of the spinal cord. The patient was tentatively scheduled for cervical laminectomy. The routine preoperative electromyogram revealed extensive bilateral lower motor-neuron disease extending from the fifth thoracic through the second sacral level. Further investigation led to the diagnosis of an ascending neuromyelitis, and the patient was placed on medical therapy.

These last two cases illustrate the difficulty in recognizing, clinically, the existence of a partial lower motor neuron lesion when there is a concurrent partial upper motor-neuron lesion in the spinal cord. Neither patient had clinically recognizable fasciculations. Cervical laminectomies were under consideration for both patients—on the first, under the impression that there was spinal-cord compression from multiple cervical-disc protrusions, and on the second patient, under the tentative diagnosis of an intramedullary neoplasm of the cervical cord.

Case 4. A white male, right-handed, x-ray technician, twenty-four years old, noted the gradual onset of numbness and paraesthesia in the right hand over a two-month period. Then, within the course of one week weakness of grasp developed in the right hand and he could not extend his right wrist. There was no pain, but there was paraesthesia in the right arm. Neurological examination revealed the right triceps to be weak, with an absent triceps reflex. There was no objective sensory loss despite subjective numbness of the entire right hand. There was no evidence of long tract involvement of the cord. General physical examination revealed the absence of the right radial pulse on abduction of the upper extremity beyond 90 degrees. Roentgenograms of the cervical spine revealed a wide transverse process of the seventh cervical vertebra on the right, but no cervical rib. Electromyography of the anterior primary divisions of the fourth cervical through the first thoracic level on the right was reported as being consistent with minimal Wallerian degeneration and demyelinization in the axons in the distribution of the anterior primary division of the seventh cervical-nerve root on the right.

It was believed that the diagnosis was either an atypical herniated sixth to seventh cervical intervertebral disc, or an anterior scalenus syndrome. The patient was put in cervical traction of seven pounds for one week, but the weakness in his right hand grew steadily worse. A myelogram of the cervical spine revealed "questionable evidence of a lesion on the right at the level of the disc between the sixth and seventh

cervical vertebrae". Before performing a cervical laminectomy, a second electromyogram was made which revealed a noticeable progression of the lesion in the anterior seventh cervical-nerve root distribution. At this time the posterior primary divisions were checked also. In contrast to the seventh cervical anterior division, only a few complex waves were elicited. It was felt that surgical intervention was indicated, but that, prior to cervical laminectomy, a scalenotomy with exploration of the right brachial plexus should be performed. After section of the anterior scalenus, the right middle brachial trunk was found to be compressed by an aberrant artery near the subclavian nerve. This was believed to be an unusually placed transverse cervical artery. After ligation and section of the vessel, a groove was seen in the nerve trunk. This was lysed with saline. After surgery, the patient had no numbness. He was discharged seven days after the operation with good strength in his right hand, and was back at work two weeks after surgery. He remained asymptomatic.

Electromyography is extremely valuable in distinguishing between the cervical nerve-root compression, caused by a herniated intervertebral disc, and a plexus injury such as is found in the scalenus anticus syndrone. Both may seem to indicate single nerve-root involvement if the middle trunk of the brachial plexus (made up of the seventh cervical-nerve root) is involved, and if only the anterior primary divisions are tested. By examining the posterior neck muscles electromyographically, the sparing of the posterior primary division in Case 4 helped to establish the correct diagnosis despite many distracting aspects.

Case 5. A previously active, heavily muscled, sixty-year-old white man with alcoholic cirrhosis received a bullet wound in the liver. During a prolonged period of convalescence he lost considerable weight which he failed to regain. After he could walk, he complained of weakness in the upper extremities, vague neck and shoulder discomfort, and atrophy of the muscles of the left hand. Neurological examination revealed no definite sensory loss, but showed a wasting of the muscles of both upper extremities and marked atrophy of the small muscles of the left hand with clinical fasciculations. The diagnosis was believed to be the amyotrophic lateral sclerosis form of progressive spinal muscle atrophy, but it was decided to have the patient admitted to the hospital for study in order to rule out a cervical-disc lesion. The electromyograms of both upper extremities at the fourth cervical through the first thoracic levels failed to reveal any lower motor neuron disease, except 50 per cent involvement in the distribution of the left ulnar nerve. The diagnosis of a tardy ulnar palsy was made, and neurolysis and transplantation of the ulnar nerve at the elbow was carried out. At surgery a very firm and thickened ulnar nerve was found. The patient was given physical therapy and an adequate diet. He made a satisfactory recovery.

Even in retrospect, after having the electromyographic report, it is difficult to reconstruct the sequence of events in this case. The patient's unaccustomed inactivity with muscle wasting after abdominal surgery masked the tardy ulnar palsy. Exactly when the ulnar nerve was injured is not known. The patient still has some occasional vague neck discomfort which may be due to cervical arthritis.

Case 6. This elderly man was admitted to the hospital for study because of a complaint of severe pain in the right side of the neck and right shoulder radiating down his arm. There were no localizing findings on neurological examination. Routine chest roentgenograms revealed a small mass in the left lung. Cervical-spine roentgenograms revealed a narrowing on the fifth to sixth cervical interspace. A cervical myelogram disclosed a large filling defect at the fifth to sixth cervical level with a minimal filling defect at the sixth to seventh cervical level, both on the right. Electromyogram revealed degeneration and demyelinization of approximately 5 per cent of the axons in the distribution of the seventh cervical nerve on the right. At cervical laminectomy a definite herniated intervertebral disc was found at the fifth to sixth cervical level on the right. Because of the electromyograph report of abnormality in the seventh cervical-nerve root the sixth to seventh cervical interlaminar space was opened. Extradural metastatic carcinoma was encountered.

Had it not been for the electromyographic report, this metastasis would probably not have been discovered at the time of surgery.

Case 7. A high-school girl, eighteen years old, was involved in a severe automobile accident in which she received a linear fracture of the skull on the left side and multiple other injuries. On admission to the hospital she was semicomatose and while she was under observation, hemiplegia developed on the right. There was also a fixed, dilated left pupil. At surgery a large extradural hematoma on the left was evacuated. After the operation, the patient remained aphasic and could not answer questions well. The hemiparaesis on the right cleared until her lower extremity became clinically normal. Her right upper extremity remained paraetic. An electromyogram revealed a right brachial plexus injury with involvement of the lateral cord.

CASE 8. A housewife, twenty-nine years old, was admitted to the hospital with involvement of the seventh, eighth, ninth, tenth, and eleventh cranial nerves on the right side. At operation a large posterior fossa neurofibroma was seen to involve these nerves and to encroach upon the twelfth cranial nerve as well. Postoperatively, a facial-hypoglossal anastomosis was contemplated, and the possibility of damage to the twelfth cranial nerve at operation was discussed. The tongue seemed strong with no atrophy or fibrillations. Three weeks later an electromyogram of the tongue was negative, and plans were made to proceed with the anastomosis.

The electromyogram in both these cases gave the necessary information before it could be reliably obtained, clinically. The facilitation of treatment in traumatic peripheral-nerve lesions, including the facial nerve, is one contribution of electromyography. In Case 7, serial electromyograms have subsequently failed to show improvement, and the patient is at present scheduled for surgical exploration of the lateral brachial plexus.

CASE 9. A white woman, sixty-four years old, came to the hospital complaining of weakness and pain in the left lower extremity. She had diabetes which she reportedly controlled by diet although she had been treated with insulin. The patient had had a myelogram and a negative lumbar laminectomy at a large Mid-western clinic. After surgery she did well for some time. Because of the return of her symptoms she was admitted to the hospital for study with the tentative diagnosis of lumbar nerve-root compression. Electromyogram revealed extensive lower motor neuron disease bilaterally throughout the sacral, lumbar, and thoracic levels.

Clinically there was little evidence to suggest widespread lower motor neuron degenerative disease. It is yet to be determined whether this case represented a diabetic neuropathy or a form of progressive spinal muscle atrophy with an associated metabolic disease, such as has been frequently reported recently.

The use of electromyography for objective substantiation in the field of functional complaints, malingering, and legal medicine is now well established. As examples we cite the following:

CASE 10. A ten-year-old girl fell at school. Thereafter, she complained of weakness of her left lower extremity. She was seen repeatedly by orthopaedists, neurologists, and by at least one neurosurgeon. Her gait was bizarre, and while there were some doubts as to the diagnosis, the patient's disability was considered to be organic. She attended a crippled children's school, wore a foot-drop brace, and walked with a limp. At the age of fourteen she was examined again, prior to a tentative operative ankle-stabilizing procedure. An electromyogram was performed which failed to reveal any evidence of organic disease. With encouragement from the electromyographer, the patient walked out of the examining room without her brace or her limp.

CASE 11. A seven-year-old boy fell and fractured his humerus. A cast was immediately applied. Several weeks later a check roentgenogram revealed poor alignment. The cast was removed, the fracture was reset, and a new cast was applied by another orthopaedist. All this was accompanied with considerable psychic trauma to the parents. When the second cast was changed, a complete radial palsy was discovered. An immediate electromyogram revealed such extensive changes that in all probability the damage to the nerve had been done at the time of the original injury. An exploration and neurolysis was subsequently performed with a good result.

There is still much to be learned regarding the clinical interpretation of electromyographic findings. For example, two recent patients, both middle-aged men with low-back and lower-extremity pain, were found, by means of electromyography, to have extensive involvement of the lumbar posterior primary divisions on the affected sides but with little involvement in any of the anterior primary divisions. At surgery, one patient was found to have sheets of metastatic carcinoma throughout his sacrospinalis muscle. The other patient proved to have an extensive adhesive arachnoiditis, probably syphilitic.

There are other unusual cases in which it is very difficult to interpret the electromyographic findings. Trying to differentiate between a rare second or third lumbar nerve-root lesion by electromyography is more difficult than when lower lumbar-nerve roots are involved. Consider the difficulty encountered in the following case:

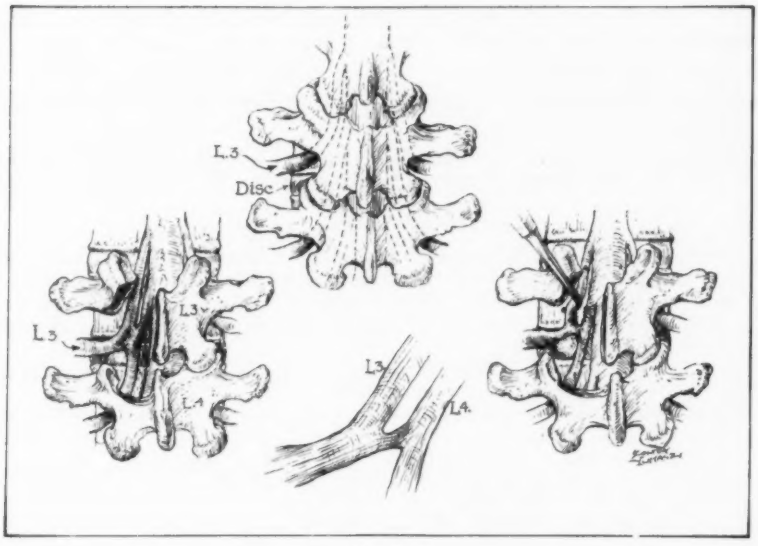

FIG. 2

Case 12. A true "plexus" inside the spinal canal involving the third and fourth lumbar-nerve roots.

CASE 12. The patient was a white woman, forty-nine years old, with a history of recurrent back pain for four years. Two months prior to admission to the hospital she lifted a heavy weight. This was followed by pain in the back and the anterior portion of the left thigh. On physical examination it was found that all movements of the patient's spine referred pain to the upper portion of her thigh. Neurological examination revealed a diminished left patellar reflex. There were no sensory changes. The electromyographic findings were consistent with approximately 10 per cent involvement in the area of the third lumbar-nerve root on the left. The myelogram revealed a slight lateral indentation at the third to fourth lumbar level on the left. The second to third lumbar level was completely negative. In view of the abnormal electromyogram, surgery was believed to be indicated. At laminectomy it was decided to examine the third and fourth lumbar level first. There was found a very small but definite lateral protruding nipple of herniated disc material (Fig. 2). The third lumbar-nerve root, instead of sweeping laterally and superiorly under the third lumbar vertebral pedicle, was pulled down and held over the protrusion by what appeared to be an adhesion to the fourth lumbar-nerve root. On careful dissection, however, a partial plexus was found inside the spinal canal, and what appeared to be an adhesion was a true sheath containing nerve fibers from the fourth lumbar-nerve root joining the third lumbar-nerve root. The disc was removed and the nerve roots were not separated. After the operation the patient made a prompt recovery.

There are times, however, even in the more common syndromes, when the electromyogram can be of little help. Although the use of electromyography is often helpful after poliomyelitis, we cite the following case as an example of the incorrect use of this test:

CASE 13. A white man, thirty-two years old, experienced an attack of acute poliomyelitis, followed by residual weakness of both lower extremities and back muscles. The patient's past history revealed recurrent low-back pain previous to poliomyelitis. Several weeks after the attack he reached down to touch the floor to demonstrate to his physical therapist how well he was doing. He immediately experienced a severe sciatic pain on the left and could not straighten up. The patient was admitted to the hospital with the diagnosis of a herniated left lumbosacral intervertebral disc. A routine electromyogram of the left lower extremity showed approximately 10 per cent involvement in all muscles tested. Fortunately the myelogram localized the lesion, and at surgery an extruded lumbosacral intervertebral disc was removed.

SUMMARY

The electromyogram is of use in the diagnosis of lesions in which the demonstration of minimal lower motor neuron disease is of importance. These lesions can often be found

in no other way. It is also of value in certain neurosurgical problems not frequently encountered. Furthermore, while the electromyogram is in no sense a substitute for a complete history and a careful physical and neurological examination, it sometimes leads to an important finding previously overlooked, or indicates the need for further investigative measures, such as myelography [2].

NOTE: The authors are fortunate in having been able to work in close cooperation with Dr. James G. Golseth of Pasadena, California. The electromyograms cited in this report were all made by him.

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Subtalar Extra-Articular Arthrodesis

A Preliminary Report of a Method of Stabilizing Feet in Children *

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Subtalar extra-articular arthrodesis, a procedure developed by Dr. William T. Green and Dr. David Grice, is a major contribution to the solution of the problem of unstable feet in children as a result of paralytic poliomyelitis.

The purpose of this paper is to review our experience over the past four years with subtalar bone-graft stabilization in children. During this time sixty-two stabilizations were performed by the authors at the Shriners' Hospital for Crippled Children in Los Angeles. The patients ranged in age from three to twelve years.

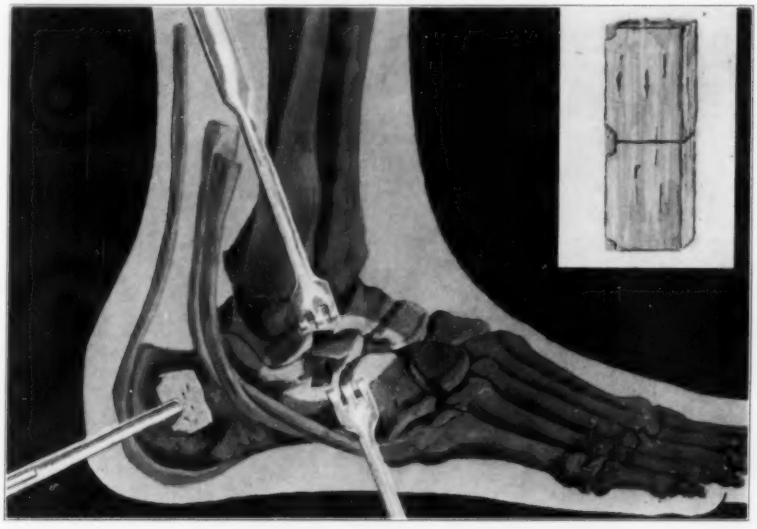

FIG. 1

Drawing showing the proper location for the slots in the roof and floor of the sinus tarsi. The full-thickness tibial graft (right) has been shaped for insertion.

The deformities treated in this series included: (1) paralytic flat feet, (2) calcaneovalgus feet, (3) flail or partially flail feet with no muscle imbalance, and (4) miscellaneous types of deformity.

SURGICAL PROCEDURE

The surgical procedure is basically the same for all types of deformity. An incision, three centimeters long, is made parallel to the skin lines over the sinus tarsi on the lateral aspect of the foot, the peroneal tendons forming the posterior margin. The cruciate ligament is incised and preserved in order to facilitate closure. The fat content is removed and the floor and roof of the sinus tarsi are cleared subperiosteally. Parallel slots are then made by means of an osteotome which is one-fourth or three-eighths of an inch in size, depending

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, February 1, 1956.

FIG. 2

The tibial grafts have been placed so that their verticle axes are parallel to the long axis of the tibia when the foot and ankle are in a neutral position.

on the size of the child. The slots are made so that when the foot is inverted and the ankle is at a right angle, the grafts will be parallel to the long axis of the tibia (Figs. 1 and 2).

The vertical length of the sinus tarsi is measured. A full-thickness graft, five to ten millimeters wide and twice as long as the sinus tarsi, is then removed from the proximal end of the tibia, just distal to the tibial tubercle, and is cut into two equal blocks. These blocks are shaped into modified trapezoids and are placed with their cancellous sides to-

FIG. 3

FIG. 4-A FIG. 4-B

Fig. 3: M. M. The posterior transplant has been placed in the center of the apophysis of the calcaneus, with the foot in an equinus position. The bone grafts are secure and are slanted obliquely forward from the talus to the calcaneus, in relation to the subtalar joint.

Figs. 4-A and 4-B: Wedging cast for correction of an equinus deformity of the talus in a paralytic flat foot. The heel has been placed in inversion so that the pressure of the calcaneus will cause correction of the equinus deformity of the talus.

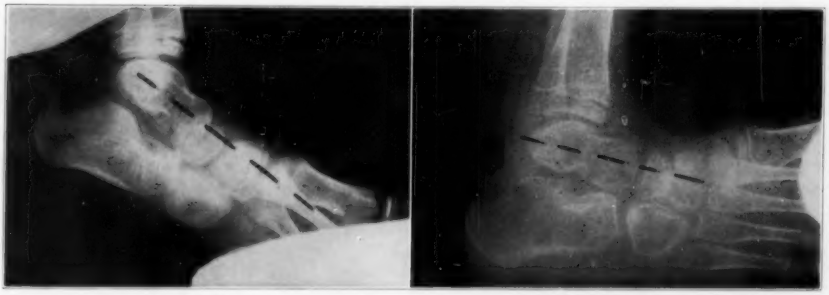

FIG. 5-A FIG. 5-B

Fig. 5-A: L. D., aged six. This roentgenogram shows fixed equinus deformity of the talus.

Fig. 5-B: The equinus deformity was corrected prior to operation by the use of wedging casts for six weeks.

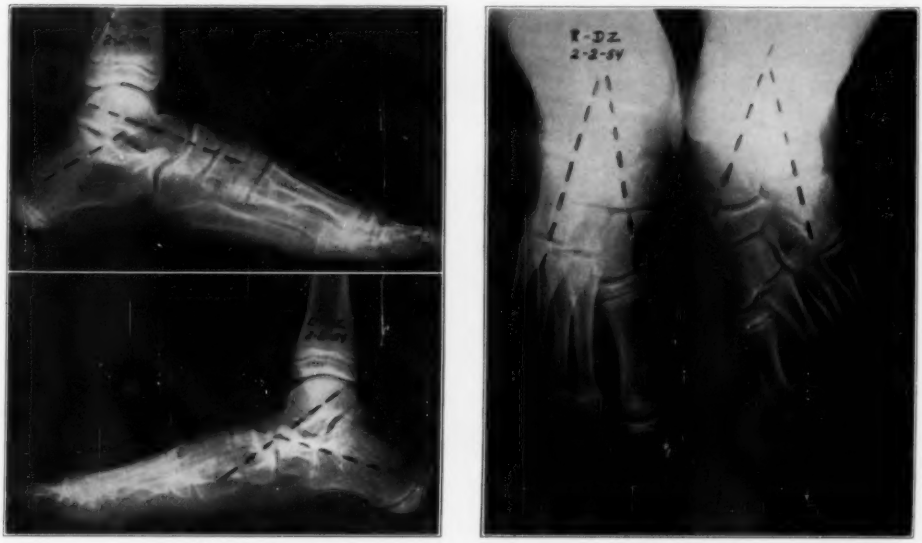

FIG. 6-A FIG. 6-B

Fig. 6-A: D. Z., a patient with paralytic flat-foot as a result of a poliomyelitis attack at six years of age. The anterior and posterior tibial muscles of the left leg were rated zero; the other muscles of the leg and foot were normal and the right lower extremity was not involved. These lateral roentgenograms of both feet were made when the patient was twelve; the lower view shows the fixed equinus deformity of the left foot.

Fig. 6-B: Anterior roentgenogram of both feet showing the posterior and lateral displacement of all the tarsal bones in relation to the talus in the left foot.

gether. They are long enough to fit snugly in the sinus tarsi and are tapped into place with a bone set and mallet. They should be placed so that they are either perpendicular to the subtalar joint or slanted obliquely forward from the talus to the calcaneus. If they are slanted obliquely backward, they will not be stable and may become disengaged as the foot swings out into eversion. Following proper seating of the bone grafts, rigid fixation of the subtalar joint and restoration and maintenance of the normal contour of the foot will be obtained.

When indicated by muscle imbalance, tendon transplantations are carried out in a conventional manner. The distal attachment is severed and the muscle and tendon are withdrawn over the area of origin and are redirected in a straight line to the new insertion.

The transplanted tendons are inserted into drill holes in the bone and secured with No. 30 or No. 28 steel Bunnell pull-out wires. In our series we placed the tendons under maximum tension, the foot being in equinus when posterior transplantation was done (Fig. 3) and in maximum dorsiflexion when anterior transplantation was done. The pull-out wire is removed after six weeks. A walking cast is then used for three or four additional weeks or until there is roentgenographic evidence of incorporation of the bone graft. In our series the average length of time before there was clinical and roentgenographic evidence of fusion was nine to ten weeks.

There were no fatalities or infections and no absorption of the bone graft in this series.

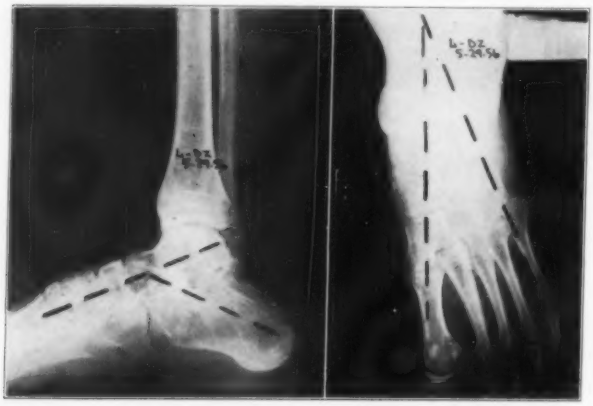

FIG. 6-C

FIG. 6-D

FIG. 6-E

FIG. 7

Fig. 6-C: Roentgenograms made two years and three months following the performance of a subtalar arthrodesis and transplantation of the peronaeus longus to the second cuneiform bone.

Fig. 6-D: Anterior views showing the foot before (left) and after the operation.

Fig. 6-E: Posterior views showing the foot before (left)and after the operation.

Fig. 7: C. B., a patient with paralytic flat-foot of the right extremity as a result of a poliomyelitic attack at four years of age. When the patient was ten, subtalar arthrodesis was performed and the peronaeus longus was transplanted to the second cuneiform bone. This roentgenogram, made one year after the operation, shows secondary narrowing of the lateral aspect of the distal tibial epiphysis.

PARALYTIC FLAT-FOOT (THIRTY-ONE CASES)

In this condition the primary muscle weakness is total or partial weakness of the tibialis anterior and tibialis posterior (of the two tibial muscles the tibialis posterior is probably the more important in maintaining the long arch of the foot). Another almost constant finding in this condition is tightening and shortening of the gastrocnemius and soleus muscles. As a result of these muscle conditions, there is lack of support for the talus on the calcaneus and with weight-bearing the talus assumes an equinus position and there is lateral displacement of the fore part of the foot, with lateral and posterior displacement of all the tarsal bones in relation to the talus.

The key factor is the loss of the normal relationship of the talus and calcaneus, and

FIG. 8-A

FIG. 8-B

L. D. (also shown in Figs. 5-A and 5-B), a patient with paralytic flat-foot of the right extremity as a result of a poliomyelitic attack at three years of age. When the patient was six, a subtalar arthrodesis was done and the peronaeus longus was transplanted to the dorsum of the foot. These photographs were made immediately before the operation.

FIG. 8-C

FIG. 8-D

These photographs, made three years after the operation, show a mild varus deformity of the right heel. The patient had no symptoms, and the function of the foot was normal.

correction of this factor will restore the normal alignment and height of the foot. The insertion of the extra-articular bone graft in the sinus tarsi on the lateral aspect of the foot is an effective means of accomplishing this correction. It has been found that following solid incorporation of the bone graft, the normal relationship of the talus to the calcaneus will be permanently maintained and, furthermore, that the bone graft interferes with the normal growth of the foot to a minimal degree, if at all. The bone graft is placed in cancellous bone in the roof and floor of the sinus tarsi, a location which is entirely extra-articular and which does not involve the endochondral plate which underlies the articular cartilage of bone in children. Another important factor is that the height of the foot is restored and maintained throughout growth.

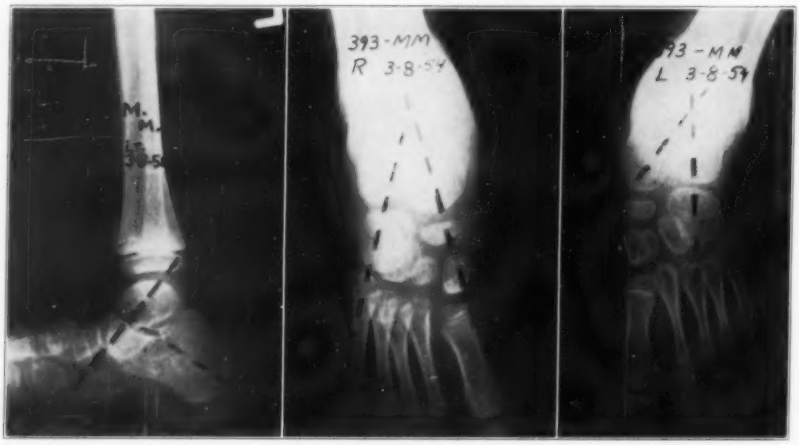

FIG. 9-A

M. M. (also shown in Fig. 3) had had poliomyelitis when one year old. These roentgenograms, made when the patient was four, show an equinovalgus deformity of the left foot.

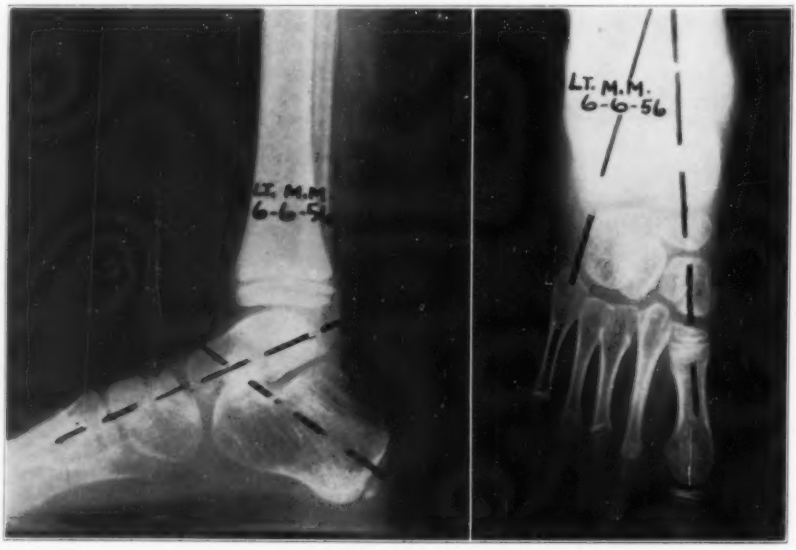

FIG. 9-B

Roentgenogram made two years and three months following the performance of a subtalar arthrodesis and transplantation of the peronaeus longus and flexor hallucis longus to the calcaneus.

FIG. 9-C

FIG. 9-D

Photographs made before the operation, when the patient was four.

FIG. 9-E

FIG. 9-F

Photographs made two years and three months after the operation, when the patient was six.

Shortening of the heel cord is of major concern in this group of patients. In the patients in our series with a tight heel cord, we attempted to obtain correction by conservative means, that is, by the Kite method of wedging plaster casts. In three of our cases, the plaster casts were removed before full correction had been obtained. To this date, we have not corrected this condition surgically. In the wedging of the paralytic flat foot, the foot is held in maximum inversion until the equinus deformity of the talus has been corrected (Figs. 4-A and 4-B).

When this primary deformity has been corrected (Fig. 5), the indicated muscle transplantations and the bone-grafting can be done at the same time. In our series, we have transplanted the strong peroneal muscle forward along the mid-line of the foot to the second cuneiform bone or to the base of the second metatarsal (Figs. 6-A through 6-E).

Complications or Errors

1. *Failure to correct the equinus deformity of the talus:* If the equinus deformity of the talus is not corrected, solid fusion of the talus to the calcaneus will occur with the fore

FIG. 10-A

FIG. 10-B

J. E., a patient with calcaneovalgus deformity of the right foot as a result of a poliomyelitic attack when one year old. These photographs were made before the operation.

FIG. 10-C

FIG. 10-D

When the patient was six years of age, a subtalar arthrodesis was done and both peroneal muscles were transplanted to the calcaneus. These postoperative photographs show residual genu valgum and external-rotation deformity.

part of the foot in abduction and the heel in fixed equinus and valgus. As a result, a strong valgus-deforming force will be transmitted to the ankle joint and the talus will become tilted within the ankle mortise upon weight-bearing. In three of our cases secondary narrowing of the lateral aspect of the distal tibial epiphysis subsequently occurred (Fig. 7).

2. *Overcorrection of the valgus deformity, resulting in a varus deformity:* There is a tendency to insert the bone graft with too much force. When the graft is in place and the drapes have been removed, the foot should be carefully inspected. The time to control this factor is at the operating table, and, if necessary, the graft should be trimmed at that time, for any attempt to perform manipulation at a later date may lead to a bad result. Three of our patients operated on three years ago have a mild varus deformity of the heel; all three have a stable, painless foot, however, and in none is the deformity severe enough to warrant further surgical correction at this time (Figs. 8-A through 8-D). The results in the remaining twenty-five patients are cosmetically and functionally satisfactory.

FIG. 10-E

FIG. 10-F

These photographs were made following osteotomy of the tibia and fibula to correct the valgus and external-rotation deformities.

CALCANEOVALGUS FEET (THIRTEEN CASES)

In this second group of patients, equally dramatic results were obtained, especially following transplantation of good muscle power to the calcaneus. Prior to operation the condition in all cases was accompanied by marked apparent deformity. Following the operation ten of the patients were able to discard the brace that they had previously required (Figs. 9-A through 9-F).

The short-term follow-up, made by means of clinical and roentgenographic examination, demonstrated that in all of the patients a definite improvement in the calcaneal deformity had been obtained by the insertion of the extra-articular bone graft and the transplantation of a muscle to the calcaneus. Dr. Green has demonstrated that the best mechanical advantage following transplantation is obtained by placing the tendon through a drill hole in the distal tip of the apophysis of the calcaneus. The pull of the muscle will thus be exerted against the major growth center of the bone (Fig. 3).

Complications

1. In marked calcaneovalgus deformity of long standing, there is frequently considerable external torsion of the tibia and considerable genu valgum. The foot will become well aligned with the ankle joint after subtalar fusion, but the child will walk with the knee and ankle in valgus positions and the ankle mortise may widen on the medial aspect. In young children, with mild deformities, we have used the Denis Browne shoe splint to correct the torsion; and, in children with severe cases of genu valgum and torsion, we have done tibial and fibular osteotomies (Figs. 10-A through 10-F).

2. Following muscle transplantation to the calcaneus, a temporary equinus deformity may result. During the first six months after surgery, this may be compensated for by the use of a heel lift which will prevent the child from forcing the ankle into a valgus position and will enhance the function of the newly transplanted muscles. In two of our cases correction of the equinus deformity by careful, slow wedging was necessary in order to enable the fitting of a normal shoe.

FLAIL OR PARTIALLY FLAIL FEET WITH NO MUSCLE IMBALANCE (THIRTEEN CASES)

The indications for stabilizing these flail feet by subtalar extra-articular arthrodesis are not yet definitely established. This operation should not be done when the flail foot is

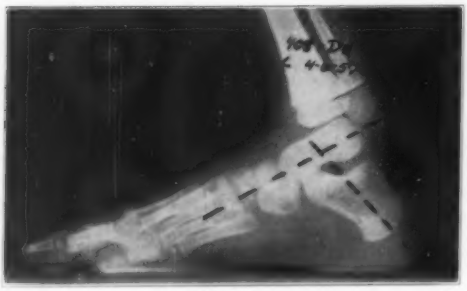

FIG. 11-A

FIG. 11-B

Fig. 11-A: Preoperative roentgenogram. D. H. had had poliomyelitis when six months old, and as a result the muscles below the knee in the left extremity were flail.

Fig. 11-B: A subtalar arthrodesis was done when the patient was five. This postoperative roentgenogram shows the improvement in the alignment of the foot obtained by the operation.

in a varus position because the use of a subtalar bone graft is not the answer to this problem. Furthermore, varus deformity of the foot and adduction deformity of the fore part of the foot cannot be corrected by this procedure. The bone-graft procedure is indicated, however, in very weak feet with marked valgus deformities as a result of weight-bearing. These weak or flail feet may require triple arthrodesis at a later date, when the bone growth is complete. It appears, however, that the further development of deformity and the necessity for this major operative procedure in later life can be prevented if the subtalar arthrodesis is performed when the deformity is first recognized (Figs. 11-A and 11-B).

MISCELLANEOUS GROUP (FIVE CASES)

The subtalar procedure has been performed on two patients who had marked painful flat-foot with no paralytic involvement, on one patient with a congenitally vertical talus, and on two patients who had previously been treated by multiple tendon transplantations.

DISCUSSION

The extra-articular subtalar bone-grafting procedure should not be done indiscriminately on asymptomatic flat feet. In patients with flat-foot deformity resulting from paralysis, however, the normal architecture of the foot may be restored and maintained by this operation.

It has recently been suggested that subtalar bone-grafting artificially produces talocalcaneal coalition and that feet with this condition may become painful in later years. We do not agree with this view, for we feel that the result of this operation will be a rigid bone bridge rather than a pseudarthrosis with the foot in a fixed (spastic) valgus position.

Fixation of the talus to the calcaneus by means of a bone graft rigidly maintains the normal relationship of these two tarsal bones. If a triple arthrodesis is indicated in later life, this procedure will be simplified by the earlier operation. The uncorrected foot with the talus in fixed equinus and the fore part of the foot in abduction is a difficult foot to stabilize by means of a triple arthrodesis.

The results obtained in this series indicate that restoration of the normal relationship of the talus to the calcaneus by use of the subtalar bone graft, in the properly selected child, is a definitive procedure that will, throughout the precious growing years, permanently maintain the correction in a painless foot.

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DISCUSSION

DR. DAVID S. GRICE, BOSTON, MASSACHUSETTS: Fusion of the subtalar joint is not a new concept. It was one of the first procedures advocated for correction of foot deformities and stabilization of the mid-tarsal region. The extra-articular arthrodesis of the subtalar joint discussed by Dr. Westin and Dr. Hall is a new approach, however. Although the initial experiences with this procedure have been promising, it still must undergo the test of time. We do not have answers to all the questions that come to mind.

The authors' experiences with the subtalar fusion are similar to our own. Instead of asking them questions (which would be unfair because I have been accumulating some good ones over the past ten years), I will attempt to give some of the answers that we have arrived at concerning the problems that have been raised by this procedure.

The first problem is whether this operation represents a definitive procedure or whether it must be followed by triple arthrodesis at a later date. The final answer to this lies in the future. There are two reasons for thinking that this procedure will not give permanent results. One reason is that in the past degenerative changes have occurred in the talonavicular and calcaneocuboid joints following subtalar fusions. We believe that these changes have developed as a result of resection of the subtalar joint, for in the young child resection of this joint disturbs the relationship between the other mid-tarsal joints and interferes with the subsequent growth of the talus and calcaneus, thus increasing the malalignment of the talonavicular and calcaneocuboid joints. Extra-articular fusion by means of bone grafts restores the normal alignment, however, and does not interfere with the growth of the foot. Furthermore, if the muscle imbalance is corrected, the normal alignment should be maintained.

The second cause for concern is that this fusion produces the same condition as that found in talocalcaneal deformity, and we are all well aware of the peroneal spasm and secondary changes that occur in the mid-tarsal joints of feet with this deformity. We have already observed two patients in whom peroneal spasm developed following fusion of the joint with the heel in a valgus position. The peroneal spasm disappeared after the feet were reoperated upon and properly aligned. I believe it is the valgus deformity of the calcaneus associated with the talocalcaneal condition that causes the peroneal spasm. If this deformity is corrected at the time of the subtalar fusion, we do not think this complication will occur. We have looked for it but have observed it in only these two patients.

How many triple arthrodesis have we done and how many will be required? We have done 108 extra-articular fusions of the subtalar joint in the past ten years. The first patient is now fifteen years old and has a well balanced asymptomatic foot. The height of the foot has been maintained, and it appears that the operation was definitive. There are only twenty-five patients in our series who were operated upon more than five years ago. Many of these are young children who have not completed their active growth, so we cannot yet determine what the final results will be. Our impression is that the majority will not require secondary triple arthrodesis.

We have already performed four triple arthrodeses in this group. Two were done because the valgus deformity had not been corrected or had recurred, and two were done because the deformity had been overcorrected and a varus deformity had resulted. It is well to bear in mind that merely inserting bone grafts in the sinus tarsi will not automatically solve the problem of the valgus foot. A little surgical judgment will be required, and the foot must be correctly aligned. If the normal position of the calcaneus beneath the talus cannot be restored or if there is deformity of the foot distal to the mid-tarsal region after the calcaneal deformity has been corrected, this procedure should not be done. When there is fixed deformity of the foot, when there is an adduction or varus deformity of the fore part of the foot, or when there is relaxation of the talonavicular and navicular-cuneiform joints, this procedure is not indicated.

Someone has asked how old the patient should be. The question is not how old the patient is but how long the deformity has been present. It is apparent that if the metatarsals rest on the ground when the heel is everted, the fore part of the foot must be in a varus position with respect to the proximal portion of the foot. This relationship will have become fixed if the deformity has been present for an extended period. In such a situation, when the calcaneus is inverted to a normal position, a varus deformity of the fore part of the foot will occur. This may correct itself in a young child during the growing period, but in the older patient it will persist and abnormal pressure will occur beneath the fifth metatarsal. This is particularly disturbing to young ladies who desire to wear high heels.

Do not be overzealous in making the correction. A varus foot may look well in the roentgenograms, but it does not "wear well".

This procedure is applicable to (1) the paralytic valgus foot resulting from poliomyelitis, spina bifida, and cerebral palsy; (2) congenital calcaneus; and (3) congenital plantar flexion of the talus with valgus flatfoot deformity.

DR. C. E. IRWIN, ATLANTA, GEORGIA: I have found extra-articular subtalar arthrodesis a very valuable

procedure for two conditions: (1) paralytic equinovalgus and (2) paralytic calcaneovalgus. I have done over sixty-five operations during the past three years, including seven during the four months I have been in Atlanta.

I would like to describe briefly the equinovalgus deformity. There is equinus of the anterior and posterior portions of the foot, abduction and eversion of the fore part of the foot, abduction and eversion of the calcaneus, and equinus but not adduction of the talus. In the presence of an extremely tight heel cord, the entire calcaneus is displaced posteriorly at the subtalar joint.

The authors stated that they stretch the contracted tendo achillis by means of corrective plaster casts prior to surgery. It seems to me that this procedure lengthens the period of hospitalization. I do a routine Hoke-type heel-cord lengthening at the time of the extra-articular arthrodesis and then do tendon transfers four weeks later. Many of the patients can go home at the end of ten days following each operative procedure, so their hospital time is cut down materially.

In inserting the grafts, which are taken from the upper end of the tibia, I place one so that it extends vertically from the neck of the talus down to the calcaneus and the other so that it extends obliquely from the junction of the neck and body of the talus forward to the anterior end of the calcaneus. The latter graft is placed in this manner in order to prevent the calcaneus from being displaced posteriorly when the foot is dorsiflexed.

I feel that it is important in placing the grafts to hold the foot in extreme equinus and inversion with the fore part of the foot adducted and supinated. This position opens up the sinus tarsi and tarsal joints and restores the normal relationship of the navicular to the talus. The ends of the grafts are embedded fully one-quarter of an inch into cancellous bone. Before the cast is applied, the foot should be locked in a good weight-bearing position.

Four weeks after the arthrodesis, the peronaei longus and brevis are transferred to the anteromedial portion of the tarsus, but not under too much tension. In one case I converted a valgus foot into a calcaneus foot by lengthening the heel cord too much and inserting the anterior transfer too tightly.

In a Correspondence Letter which I wrote in May 1954, I stated that swelling is not a problem. I have since learned that a slough may develop on the dorsum of the foot in the region of the navicular if the cast is too tight. I have had this unfortunate experience on two occasions in the last three months.

I routinely apply a brace and socket-fit or tarso-supinator shoe with an inner-roof wedge, and I allow weight-bearing at the end of ten weeks.

Although one cannot draw definite conclusions after such a short period of follow-up, I am sure that some of the feet I have treated will not need triple arthrodesis. They are now more nearly normal in appearance than they will be later if triple arthrodesis is done. The surgical procedure is comparatively minor. The youngest child on whom I have done this procedure was three and one-half years of age and the oldest was nine. I plan to perform the arthrodesis on a twelve-year-old boy in the near future, and I am sure it will solve his problem. Three years ago I would not have chosen this procedure but would have done a triple arthrodesis instead.

Further Evaluation of the Use of Intramedullary Nailing in the Treatment of Gunshot Fractures of the Extremities *

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In 1952, the author and Jeffress reported the end results obtained in eight infected gunshot fractures of the femoral shaft treated two years previously by means of intramedullary nailing. These fractures were thoroughly debrided and a modified form of nailing was performed, all the wounds being left wide open for drainage. One wound was subsequently treated by skin-grafting, but most were permitted to heal by secondary intention. The results were most gratifying. Two additional patients have since been treated in a similar manner. In all ten patients satisfactory union was obtained although in one patient there was dense fibrous union rather than bone union; this patient did not require a brace. Three patients still had slight residual intermittent wound drainage after two years.

The current use of this method springs from the temerity of certain German surgeons who applied the principle of intramedullary fixation to the treatment of gunshot fractures during World War II. In the 1940's Küntscher [13, 14], Böhler [1, 2], and others advocated the use of this method in relatively clean wounds at the time of delayed or secondary closure. Heim, in 1943, and Haebler, in 1950, reported its successful use even in severely contaminated or frankly suppurative gunshot fractures, stating that the immobilization provided by the nail resulted in relief of pain, reduction of local infection, gradual healing of the wound, improvement in the patient's general welfare, and eventual union of the fracture. These claims have been substantiated not only by the results obtained by the author and Jeffress but also by the results obtained in a similar series of patients treated by Carr and Turnipseed. Use of this method in selected cases has also been advocated by Strasser, Teneff, Wasastjerna, and Key.

During World War I, Hey Groves utilized the principle of metallic internal fixation in the treatment of selected gunshot fractures. This principle was also followed by Hampton and his associates in their work in the Mediterranean Theater during World War II. The end results of the latter group have remained in doubt, however, for the enthusiasm expressed by those who used the method overseas was not always matched by that of the surgeons who received the patients in the Zone of the Interior. Apparently in many of the patients there developed late infections which may have interfered with bone healing and affected the eventual end result. A thorough investigation of these cases is now under way and will be reported by Godfrey.

Successful use of modified intramedullary nailing during the early months of the Korean conflict has borne out the previous good reports of the Germans and has been the basis for an increasing use of this procedure in gunshot fractures with infection. The fact that it has been employed by inexperienced operators in poorly selected cases readily explains why there have been some unfortunate results. Since, if properly applied, this method has great usefulness, it is felt that its indications and limitations should be clarified.

In an attempt to determine the circumstances under which intramedullary nailing of gunshot fractures might be usefully and safely applied, a study was made of the records of United States Army Korean War casualties whose fractures had been treated by this method. The records of eighty-five such patients were located and were carefully analyzed in order to determine the circumstances under which the nailing had been done, the time

* Read at the Annual Meeting of The American Orthopaedic Association, Banff, Alberta, Canada, June 20, 1956.

between injury and nailing, the presence of infection, the postoperative course, and the short-term end result. In addition, a detailed questionnaire was mailed to these patients to determine their present condition, especially regarding wound healing, fracture healing, and residual disability. From sixty-seven patients (78.8 per cent) we received follow-up information which covered a minimal postoperative period of two years, enabling us to be reasonably certain of the end results. This series included a total of seventy gunshot fractures treated by intramedullary nailing.

FRACTURES NAILED BEFORE WOUND HEALING

The operations could be divided into two groups, those performed prior to wound healing and those performed subsequent to complete healing of the wound. There were twenty-eight fractures treated prior to wound healing. These included nineteen femoral fractures, and nine fractures of the forearm. The results were graded as *excellent* if there was both bone union and wound healing, *good* if there was bone union but intermittent slight drainage, and *poor* if there was non-union, severe chronic bone infection, or significant residual disability due to poor healing of the fracture.

In the group of nineteen patients with femoral-shaft fractures treated by intramedullary nailing at the time of delayed wound closure, there were sixteen satisfactory results (84.2 per cent). Ten of these were classified as *excellent* and six as *good*. These nineteen patients could be divided into three groups: those in whom the wound was closed immediately after nailing, those in whom the wound was not closed until after a few days' delay, and those in whom the wound was left open. Of the six patients in whom the wound was closed immediately, four had satisfactory results and two had poor results. Of the two patients whose wounds were closed after a delay of a few days, both had satisfactory results. There were eleven patients with femoral-shaft fractures which were nailed but were not considered suitable for wound closure. Of these eleven, ten had successful results.

In the group of nine patients with fractures of the forearm, eight of the wounds were closed at the time of the nailing procedure, three of them being also treated by the application of full-thickness skin flaps. A satisfactory end result was obtained in all of these patients. In one patient the wound was left open and was permitted to heal by secondary intention. This patient also did well.

In the total group of twenty-eight patients treated before wound healing, twenty-five (89.3 per cent) had good or excellent results. Of the sixteen patients in whom there was wound closure either at the time of nailing or a few days afterward, fourteen (87.5 per cent) had satisfactory results. Of the twelve remaining patients whose wounds either were permitted to heal by secondary intention or were subsequently treated by skin coverage, there were eleven (91.7 per cent) with satisfactory end results.

An analysis of the failures revealed that the two failures which occurred following immediate wound closure at the time of nailing were the result of using this closed procedure when there was frank suppuration, a definite error. These patients might have done well if the wounds had been left open. In one, amputation was necessary and in the other there was chronic infection and non-union. If these two obvious mistakes had been avoided and if immediate or slightly delayed skin closure had been performed only on wounds which appeared surgically clean, there would have been no failures in this group.

The one failure which occurred in the group of patients in whom the wound was left open was the result of chronic infection and non-union. It is felt that this failure, which led to amputation, might have occurred with any method of treatment because of the severity of the infection and the degree of bone injury.

In the twenty-eight cases in which the fractures were nailed before wound healing, the average period between injury and nailing was two months. The shortest period was one week and the longest seven months. Of the fourteen fractures which were nailed before wound healing and closed immediately, ten broke down after surgery and drained for

periods ranging between four months and thirty-seven months, the average period being nineteen months. The two in which closure was delayed for a few days drained six and eight months, respectively. In the twelve cases in which the fractures were not closed either at the time of surgery or shortly thereafter, the period of wound healing varied between two months and forty-eight months, the average period being eighteen months.

FRACTURES NAILED AFTER COMPLETE WOUND HEALING

Forty-two operations were performed after complete wound healing. The fractures treated included nineteen femoral fractures, nine humeral fractures, four tibial fractures, and ten fractures of forearm bones. In this group there were thirty-seven (88.1 per cent) satisfactory results.

In the group of nineteen patients with femoral-shaft fractures, eighteen of the results (94.7 per cent) were considered satisfactory, fourteen being classed as *excellent* and four as *good*. In the one patient with a poor result, the failure was attributed to chronic osteomyelitis and to stiffness of the knee caused by penetration of the knee by the nail. The fracture in this patient eventually healed.

In the group of twenty-three patients with fractures of long bones other than the femur, nineteen of the results (82.6 per cent) were considered satisfactory, fifteen being classed as *excellent* and four being classed as *good*. In four patients in this group, non-union resulted. Three of these non-unions were associated with infection, one of them being also associated with massive bone loss. The other non-union was of undetermined origin.

An analysis of these failures revealed that in one patient chronic infection with repeated drainage had been present for several months prior to secondary wound closure and subsequent nailing. This infection was apparently latent and the nailing was probably premature. In the other patients with non-union there was no apparent reason for the failure. It would seem that the particular method cannot be held responsible, since open reduction was necessary in all of the patients. The incidence of failure in this series was no greater than is to be expected under similar circumstances with any form of treatment. The failures occurred in three patients with fractures of the humerus and in one patient with a fracture of the radius. The time between injury and nailing in the forty-two cases of fractures treated after wound healing varied between two weeks and twelve months, the average being four months.

DISCUSSION

The use of internal fixation in fractures with obvious or probable infection is contrary to the known principles of good surgery; to close wounds under such circumstances signifies poor surgical judgment. While it must be emphasized that these fundamental principles are still sound, it is apparent that some modification is indicated in view of recent experience. The known end results in this group of patients are numerically too small to be of statistical value and yet the inferences which may be drawn seem so clear that they must be considered of practical importance in our future management of gunshot fractures.

There is no need to dwell on the acknowledged benefits [3,4] with regard to wound healing, fracture immobilization, and general welfare which are obtained when, under optimum operating circumstances, selected gunshot fractures are treated by intramedullary nailing. There is also little need to expound upon the dangers of the method when it is used improperly and under adverse circumstances. It is still our firm belief that if the optimum operating conditions do not exist, gunshot fractures should never be treated by any form of intramedullary nailing.

The indications for and the limitations of intramedullary nailing in the treatment of gunshot fractures should be clarified. It is our feeling that nailing should never be performed at the time of primary wound débridement; there is too great a possibility that infection, including the anaerobic variety, will occur, even after adequate débridement.

If infection does occur, the presence of the nail and the periosteal stripping which is a necessary part of the procedure may lead to necrosis of the bone at the fracture site or to the spread of the infection along the medullary canal (Figs. 1, 2-A, and 2-B). For this reason, it is wiser to defer nailing at least until the usual time of delayed wound closure.

On the other hand, it can be categorically stated that intramedullary nailing may be safely employed in selected gunshot fractures in which complete and uneventful wound healing has occurred. The indications for and the limitations of intramedullary nailing in these fractures are the same as they are in closed fractures. The necessity of waiting is a disadvantage, of course; however, although in some instances wound healing may be so prolonged that the nailing procedure becomes unnecessary, in many cases the waiting period is only two or three weeks. In general, this delayed method is considered the most appropriate treatment for the great majority of fractures in which nailing is necessary in order to obtain adequate immobilization.

FIG. 1

Anteroposterior and lateral roentgenograms of a femoral fracture three months after intramedullary nailing. The nailing was performed before wound healing, with immediate wound closure. Infection subsequently developed, and this, together with the periosteal stripping done in association with the nailing, led to necrosis at the fracture site. This result demonstrates one of the dangers of doing immediate closure when the nailing is performed at the time of primary débridement or at the usual time of delayed wound closure.

The patient who presents the greatest problem is the one in whom early internal fixation of the gunshot fracture is urgently required for any of several reasons. These reasons may include (1) marked loss of soft tissue or bone which makes conservative management impractical, (2) severe pain and debility because of inadequate conservative fixation, (3) prolonged frank infection which has developed as a result of unsatisfactory immobilization in spite of adequate drainage, and (4) the need to move the patient in order to treat severe associated injuries. If any of these circumstances is present, serious consideration must be given to the use of intramedullary nailing; this procedure not only may be helpful but even may save the patient's life (Figs. 3-A through 4-B).

From the results obtained in this small series of gunshot fractures, it would appear that in selected cases the risk to the patient of nailing through an open wound is no greater than that of nailing after complete wound healing. This should not be interpreted, however, as a reason to advocate indiscriminate early nailing; this procedure should be considered only under proper circumstances and in cases which fall into one of the categories just described. When improperly used, as demonstrated by the two patients whose wounds were closed in the presence of infection, the result may be disastrous. To the particular

FIG. 2-A

FIG. 2-B

Fig. 2-A: Anteroposterior and lateral roentgenograms of an infected gunshot fracture of the femur six months after treatment by the modified nailing procedure with all wounds left wide open. The nail was removed five months after the operation because of persistent draining. (It is now our policy to retain the nail in such cases, regardless of drainage, until definite union or non-union can be clinically established; this ordinarily requires at least twelve months.)

Osteomyelitis developed in the distal portion of the nail tract and was undoubtedly spread by the nail. This complication is one of the dangers of performing any type of intramedullary nailing, with or without wound closure, but is especially apt to occur in fractures which are associated with contaminated wounds and which have been nailed prior to wound healing.

Fig. 2-B: Anteroposterior and lateral roentgenograms showing healing of the osteomyelitic lesion following extensive saucerization. Bone union is present at the fracture site.

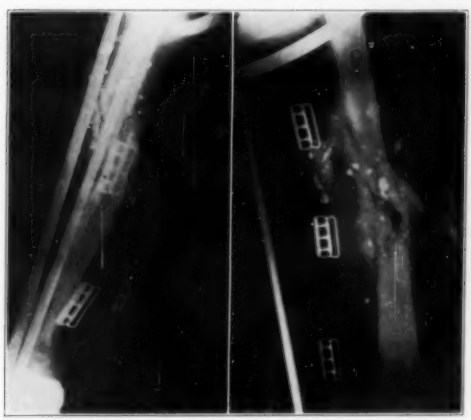

FIG. 3-A

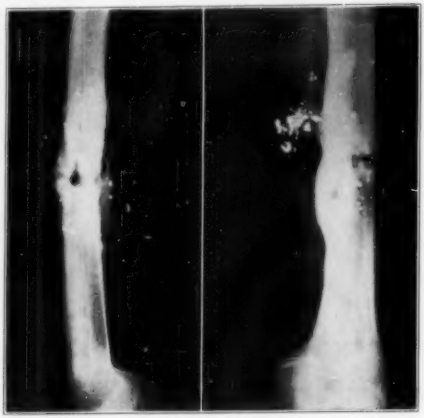

FIG. 3-B

Fig. 3-A: Anteroposterior and lateral roentgenograms of a severely comminuted infected gunshot fracture of the femoral shaft. This fracture was subsequently treated by the modified nailing procedure, all wounds being left wide open.

Fig. 3-B: One year after nailing the bone had united. Slight intermittent drainage was still present, but the functional result was good. There had been definite clinical evidence of union at eleven months, and the nail had been removed at that time.

FIG. 4-A

Posterolateral wound in the thigh of a man with an infected gunshot fracture. The fracture was treated by the modified intramedullary nailing procedure.

FIG. 4-B

The wound was permitted to heal by secondary intention. This photograph, made ten weeks after the nailing, shows that healing is almost complete. Two weeks later the healing was entirely complete, and since then there has been no further drainage. Bone union was also obtained, and the functional result was excellent.

patient in whom the disaster occurs, the incidence of success of the method in general is of no interest. For him there has been total failure.

There is an element of risk in any surgical procedure. The risk to the selected patient treated by intramedullary nailing at the time of delayed wound closure can be minimal if the method is properly employed. This study has clearly demonstrated that immediate

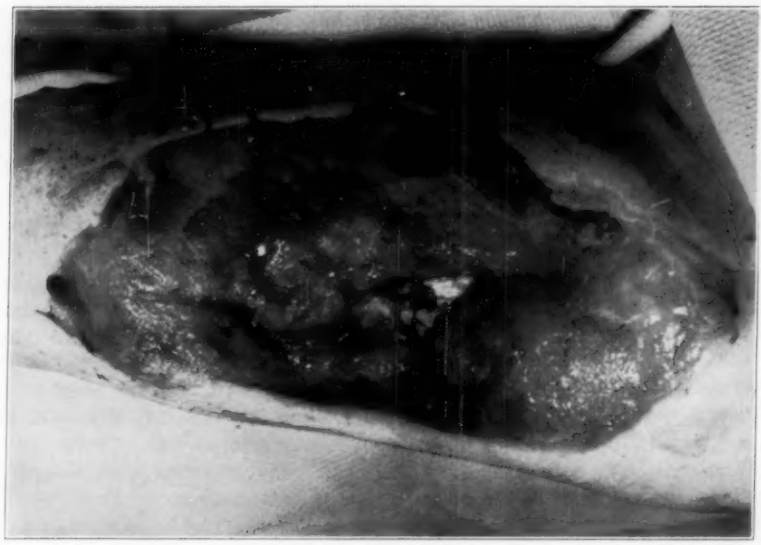

FIG. 5-A

Wound on the posterolateral aspect of the thigh of a man with a comminuted infected femoral-shaft fracture. This photograph was made one week after modified intramedullary nailing had been done.

FIG. 5-B

Photograph made two weeks later. The wound has been partially covered by split-thickness skin grafts. Further grafting was subsequently performed, but slight drainage persisted for a year. The functional result was excellent, with solid bone union and complete wound healing.

wound closure cannot be safely accomplished in the presence of infection. Infected wounds, if nailing is indicated, should be left wide open and the possibility of subsequent skin coverage should be kept in mind (Figs. 5-A and 5-B). It has also been shown that while it is possible to obtain immediate skin closure of healthy granulating wounds at the time of nailing, most of these wounds later break down and drain for long periods even though the fractures may eventually heal. It may be inferred that even when the wound appears clean, a further delay of a few days may determine more clearly whether skin closure

should be done or whether the wounds should be left open. A final conclusion of this study is that when appropriate, properly treated fractures are managed by the modified nailing technique, the wounds being left wide open for drainage, there is an extremely high percentage of satisfactory results and that, furthermore, the failures cannot be attributed to any inherent fault in the surgical procedure itself. It should be emphasized here that, when the modified nailing procedure is used, dependent drainage must be established either through the original wound or by operative incision.

SUMMARY

1. Seventy gunshot fractures of the extremities were treated by intramedullary nailing. In sixty-two (88.6 per cent) of these fractures, the functional result was satisfactory.

2. Twenty-eight of the fractures were nailed prior to wound healing. In twenty-five of these fractures the results were satisfactory. In the group of fractures treated by immediate or slightly delayed wound closure, fourteen (87.5 per cent) of the results were satisfactory; and in the group of fractures in which the wounds were left wide open following nailing, eleven (91.7 per cent) of the results were satisfactory.

3. In the group in which nailing was done subsequent to complete wound healing, thirty-seven (88.1 per cent) of the end results were satisfactory.

4. No fracture should be treated by intramedullary nailing unless the optimum operating conditions are present.

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(Continued on page 553)

Intramedullary Wire Fixation of Mallet-Finger *

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Rupture of the extensor tendon of the finger is reputed to be the most common of all tendon injuries. The resulting mallet-finger deformity is not only unsightly but is attended by a definite disability. Using a typewriter, picking up small objects, and even putting on a pair of gloves becomes a problem.

Although statistics are lacking concerning the merits of the various forms of treatment, the prevalent attitude is one of pessimism, especially with regard to ruptures not treated within one week of injury.

Pratt's report of 1952 indicates that the intramedullary-wire technique is a decided improvement over the various splints and gadgets heretofore advocated. He reported that six fresh ruptures had been treated by the closed wire method and that an additional six older ruptures had first been subjected to open operation but had then been immobilized by the intramedullary-wire method. He expressed the opinion that only ruptures of less than one week's duration are appropriate for the closed method, while older injuries require operative repair. The majority of surgeons discussing this problem have expressed similar opinions. Pratt reported no complications, merely stating that full extension was restored in the fresh ruptures and that useful extension was obtained in the older ruptures which had been subjected to open operation.

In this paper we will discuss the technique of treatment by closed wire fixation with an analysis of a series of twenty injuries in nineteen patients. Ten patients were treated within one week of injury; of the remaining patients, five were treated within one to three weeks of injury, two were treated one month after injury, and one was treated six months after injury. In four patients there was an associated fracture of the proximal lip of the distal phalanx, one of these fractures being compound.

METHOD

Pratt recommended placing a Kirschner wire through the hyperextended distal joint and then passing it just volar to the proximal joint between the joint and the flexor tendons, the proximal tip of the wire remaining embedded in the proximal phalanx. By this method both joints are immobilized with one wire, which is cut off under the skin so that no dressing is required.

This procedure was done in several of our patients but was then discarded in favor of immobilizing only the distal joint with the wire (Fig. 1-A), the proximal joint being maintained in 60 degrees of flexion by means of skin plaster. There were several reasons for this change:

1. The technique is much less difficult and does not require repeated introductions of the wire in order to make a satisfactory placement. Thus, trauma to the finger is reduced (Figs. 1-B and 2-A).

2. In three of the fingers in which Pratt's technique was used, there resulted distressing, permanent, painful limitation of motion of the proximal interphalangeal joint, presumably because the wire traversed either the joint capsule or the flexor tendons. Placing the wire as Pratt recommended is not as simple as it might appear.

3. It is possible to obtain more hyperextension of the distal joint when the wire has to cross this joint only (Fig. 2-B). This factor may be the reason that the results in some of the older injuries were much better than we had anticipated.

The minimum period of immobilization was three weeks and the maximum period

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1956.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Typical example of wire fixation of the distal joint following rupture of the extensor tendon.

Fig. 1-B: The wire shown in this roentgenogram was bent by accidental forced flexion. It was later hyperextended and straightened, and the patient obtained a normal finger.

FIG. 2-A

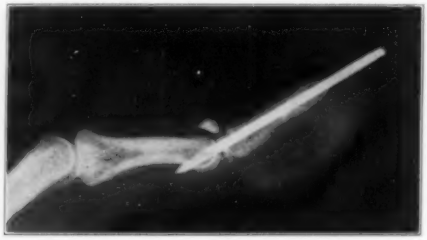

FIG. 2-B

Fig. 2-A: Anteroposterior roentgenogram showing the position of the wire. There is no evidence of epiphyseal injury as a result of the insertion of the wire.

Fig. 2-B: This roentgenogram illustrates the degree of hyperextension possible.

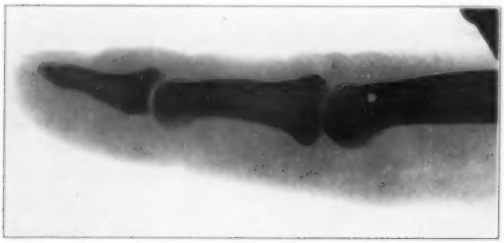

FIG. 3-A

FIG. 3-B

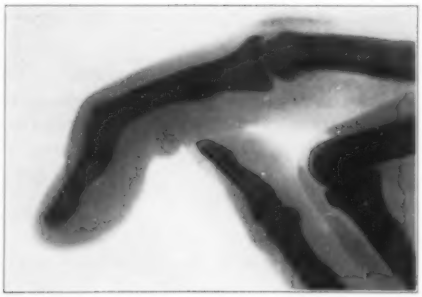

FIG. 3-C

Fig. 3-A: Full extension in a good result.

Fig. 3-B: Maximum flexion in a good result.

Fig. 3-C: Maximum flexion in a good result with the distal interphalangeal joint stabilized.

FIG. 4

FIG. 5

Fig. 4: Full extension was obtained following treatment, which included formation of a dorsal lip. The functional result was good, but the cosmetic result was poor.

Fig. 5: Lateral roentgenogram showing the maximum extension possible in a fair result. Slight hyperextension of the proximal joint is evident.

FIG. 6

Maximum extension of the distal interphalangeal joint in a poor result. Flexion of the joint was considerably reduced.

was five weeks, the majority of the fingers being immobilized for four weeks.

RESULTS

There were nine results classified as *good*, meaning there was full active extension of the distal phalanx with slight or no limitation of flexion (Figs. 3-A, 3-B, 3-C, and 4). There was, of course, no limitation of motion in the proximal joint. These patients considered their fingers to be normal.

Seven results were considered *fair* (Fig. 5). There was active, but not full extension of the distal phalanx, the loss of motion being 5 to 10 degrees, and there was often some loss of flexion, averaging about 15 degrees. These patients had a useful range of motion, however, were able to carry on their work, and did not consider themselves handicapped, although the appearance of the finger left something to be desired. In this group there was a typist and an automobile mechanic.

There were four *poor* results, due primarily to faulty technique (Fig. 6). As previously mentioned, three of the wires used to immobilize the proximal joint resulted in permanent flexion contracture of this joint. In one of these patients there was the same drop-finger deformity after treatment as before; of the twenty fingers treated, this was the only one in which this result was found.

In the fourth patient, the wire was placed dorsal to the distal joint through the joint capsule. This patient regained little or no flexion of the joint, presumably as a result of capsulitis which was caused by the presence of the wire. Because of the possibility of this reaction, we prefer not to permit the wire to come into contact with the capsule, ligaments, or tendons. There has been no evidence of any untoward reaction to the wire in the bone or cartilage.

DISCUSSION

The results achieved by both early and late treatment in this series were gratifying. The best results were in those patients treated early, but even the patients treated late

did well when the technique was not faulty. The patient who was treated three months after injury, a sixteen-year-old boy, had a normal finger after treatment. The patient in whom six months had elapsed since injury, a twenty-year-old boy, was considered to have a fair result.

Perhaps the immobilization of the finger in a position of extreme hyperextension is the reason that the patients treated late usually responded favorably. When the distal joint is placed in 20 to 30 degrees of hyperextension, enough shortening of the tendon takes place to permit the finger to regain its extensor power and to stabilize the joint. Measurements made on an articulated skeleton have indicated that 1.5 millimeters of shortening results when the finger is extended from a neutral position to 30 degrees of hyperextension.

Stiffness and flexion contracture of the proximal joint, which occurred in three of our patients, is disabling and may be painful. Stiffness of the distal joint, however, is attended by surprisingly little disability. This point has been brought out by careful interrogation of our patients. Stability of the distal interphalangeal joint is all-important and results in a very serviceable finger even when all but a few degrees of motion has been lost.

As an example of this, one of our patients, an automobile mechanic, stated that he was in no way incapacitated by the fact that his joint was in a position of extension with only about 10 degrees of flexion. By contrast, his brother-in-law, who had undergone an unsuccessful attempt at open repair ten years previously, had tried in vain to get surgeons to amputate this joint because it was always in the way.

OTHER COMPLICATIONS

Several patients had considerable pain for about twenty-four hours after the introduction of the wire. Repeated attempts at insertion and the use of a wire that was too large (we now use a .045-inch wire) may have been the cause of this pain. A patient with this complication may notice for months afterward that this finger will not tolerate cold as well as the other fingers. It is our feeling that this condition may be a mild or borderline causalgia.

Occasionally a mild loss of tactile sensation in the finger tip is seen following removal of the wire. This disappears quite promptly and has not been a problem.

Despite these complications we feel that the modified Pratt technique is the method of choice. Although the idea of immobilizing two joints by one wire with no dressing has great appeal, we feel that the alternate method of wire fixation of the distal joint with plaster immobilization of the proximal joint is preferable because of its simplicity and because of the reduced danger of complication.

SUMMARY

The modification of Pratt's technique used by the author appears to give a high percentage of good results in fresh ruptures and to provide a useful finger, occasionally even a normal finger, in older ruptures. It will probably give better results than open operation in the older ruptures, unless the surgeon is especially skilled and experienced in the treatment of this condition.

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DISCUSSION

DR. STERLING BUNNELL, SAN FRANCISCO, CALIFORNIA: It is a pleasure to hear of the good results obtained by the authors in their use of this method. Watson-Jones has written, "Preserve us from the proposals recently made of intramedullary fixation by pins driven through the pulp across the phalanges and

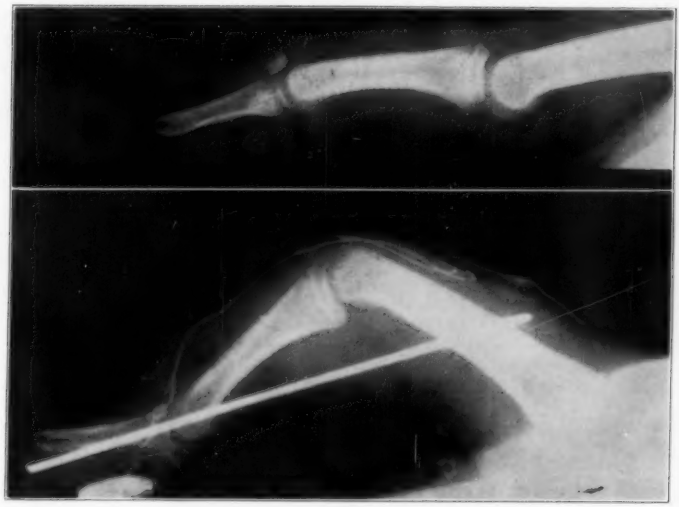

FIG. A

Pratt's method of internal fixation.

interphalangeal joints." As the authors have stated, the complications in their series were the result of faulty and repeated placing of the wire. Pratt, who originated this method, has become so proficient in placing the wires that since he made his original report in 1951, we have had him do most of the operations in our series of fifty-one cases. If a wire goes off the proper course in the process of insertion, it is left in place until a second wire has been correctly inserted. Otherwise the second wire may follow the same channel as the first. In the last twenty-two operations Pratt has used a precision guide that ensures correct placement of the wire. It was invented by Dr. Joseph T. Moreau of Edmonton, Canada, in order to eliminate repeated trials.

External splinting to hold the proximal interphalangeal joint in flexion and the distal joint in hyperextension is a difficult and unsatisfactory method; for this reason internal splinting alone has been our method of choice. The wire is cut off beneath the skin and, after a month, is withdrawn under novocain. A plaster cast is superfluous. A wire that spans only one joint will migrate, but a wire that spans two joints will stay fixed. If the proximal interphalangeal joint is too flexed when the wire is inserted, straightening may be

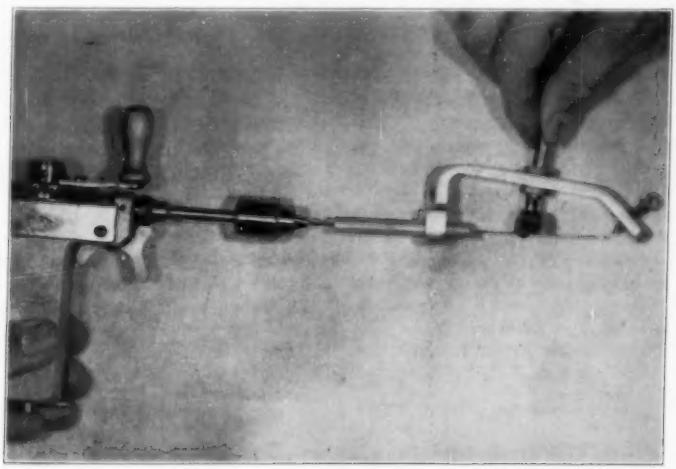

FIG. B

The guide invented by Dr. Joseph T. Moreau.

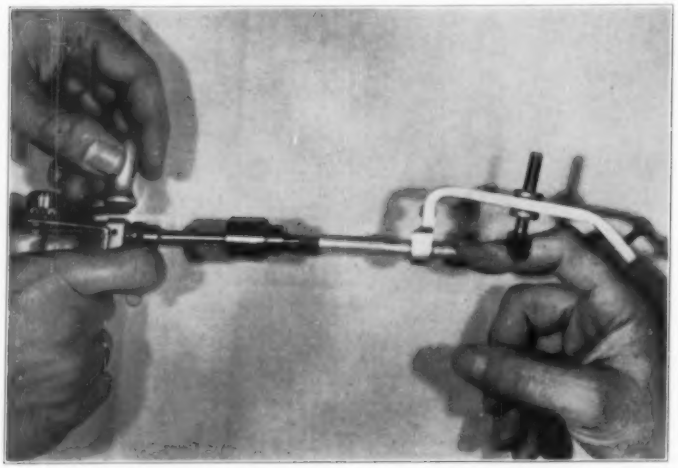

FIG. C

Method of placing the Kirschner wire in the finger.

delayed; and if the distal joint is hyperextended too forcefully, pressure ischaemia may develop in a line across the dorsum. For patients with injuries over ten days old we use the open method, but splint the finger by means of a Kirschner wire. We have found that following this procedure the tendon is generally united but too long. A withdrawable stainless-steel wire is then spliced into the tendon. This wire, which is fastened through the fingernail, will act as a cinch stitch, such as is used in eye operations, that is, it will shorten the tendon, with the result that it is not always necessary to cut and resew the tendon. Often, and especially after laceration, the tendon becomes adherent to the back of the head of the middle phalanx. In our early cases, we treated this condition by placing slippery fascia beneath the tendon. Later we found that a piece of polythene placed between the tendon and the bone was satisfactory. The polythene should be removed in a month, however, as otherwise it may be extruded. Our results have been good, although frequently the range of motion has been satisfactory rather than complete. Dr. Pratt will report our results next year.

Figure A shows the wire in place. No dressings are necessary in this procedure. The precision guide invented by Dr. Moreau is illustrated in Figure B, and the method of inserting the wire is shown in Figure C. The Kirschner wire is placed through a cannula, to which the guide is attached. The patient's finger is placed in the guide with the dorsal aspect of the proximal phalanx against the set screw and the tip of the distal phalanx against the end of the cannula. The Kirschner wire is then drilled in.

DR. CASSCELLS (concluding): The invention of a guide is, I think, a significant contribution. Obviously there is a need for some method of inserting the wire easily and quickly, and perhaps this is the answer. As we have not had a guide, we have used the simpler method which we have just presented. We have had no difficulty with the wire migrating; on the contrary, in several instances we have had considerable difficulty extracting the wire because it was so tightly embedded in bone.

I, too, have read Watson-Jones' comment in his book. I must confess I was somewhat perplexed because he does not object to placing wires in the finger for the treatment of other conditions but condemns its use for the treatment of rupture of the extensor tendon. His brief, abrupt, and unqualified condemnation has not changed my thinking on this matter.

We are also concerned about the degree of hyperextension in some of our patients. I wish to stress, however, that we have placed the joint in only as much hyperextension as is possible without using force. As there is a considerable variation in the mobility of the distal joint and in its range of extension, it did not seem logical to us to fix all fingers in the same degree of hyperextension. As we said previously, this approach may be responsible for the fact that the results in the older injuries were better than we had anticipated.

Finger Deformities Caused by Rheumatoid Arthritis

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The rheumatologist, in his daily practice, meets too many patients with neglected finger deformities. The primary fault seems to be our scanty knowledge of the problem, for, until recently, these important lesions were mentioned only briefly in the medical literature. In the past few years Bunnell [1-3] has described a number of deformities caused by muscle contraction and the subsequent progressive fibrosis, and, in 1952, Steindler stated that the two principal arthritic deformities of the hand and fingers are claw-hand and pill-roller hand.

TABLE I

INCIDENCE OF DIFFERENT DEFORMITIES

	Total	Men	Women	Children
Patients examined	305	93	189	23
Hand symptoms	288	86	184	18
Fusiform swelling only	101	43	50	8
Ulnar deviation	91	18	69	4
Contraction of collateral ligaments	5	1	4	
Buttonhole deformity	111	22	84	5
Baseball-finger, non-traumatic	10	2	7	1
Swan-neck deformity	44	12	30	2
Spontaneous rupture of extensor pollicus longus	2	2		
Tendon nodules in flexors	47	8	39	
Tendon nodules in extensors	14	4	10	
Trigger-finger	16		16	

MATERIAL

Our series consisted of 305 patients, including ninety-three men, 189 women, and twenty-three children, in whom the diagnosis of rheumatoid arthritis had been adequately verified. Of these patients—who represented the different stages of arthritis from the beginning to the burn-out stage—as many as 288 had some anatomical signs of the disease in their hands. In 147 patients, the duration of the hand symptoms had been three years or less.

The main lesions are shown in Table I.

Fusiform Swelling

One hundred and one patients, including forty-three men, fifty women, and eight children, had, as their only deformity, the typical primary lesion, a fusiform swelling of the proximal interphalangeal joints, with or without hydrops.

Ulnar Deviation

Ulnar deviation at the metacarpophalangeal joints was found in ninety-one patients, including eighteen men, sixty-nine women, and four children. This subject has been discussed in the light of results from other material in an earlier paper from our clinic [9].

Contracture of the Collateral Ligaments

Inability to flex completely the basal phalanges was found in five patients. This restriction is a well known sequel of traumatic hand conditions, and in rheumatoid arthritis, as in other conditions, it seems to arise from shrinkage of the collateral ligaments (Fig. 1).

Buttonhole Deformity of the Fingers

In this series buttonhole deformity, with flexion of the proximal interphalangeal joints and extension of the distal interphalangeal joints, was the most common deformation (Fig. 2). It was found in 111 patients, including twenty-two men, eighty-four women, and

FIG. 1

FIG. 2

Fig. 1: Contraction of the collateral ligaments resulting in inability to flex the metacarpophalangeal joints.

Fig. 2: Different stages of buttonhole deformity.

Fig. 3. Buttonhole deformity is caused by herniation of the proximal interphalangeal joint between the lateral slips of the extensor tendon and distension of the attachment of the medial slip.

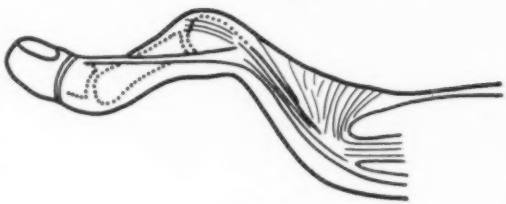

FIG. 3

five children. It was present in the index finger seven times, in the middle finger thirty-four times, in the ring finger fifty-five times, and in the little finger fifty-three times.

The mechanism of this deformity seems to be the same as that of traumatic buttonhole rupture of the middle slip at its insertion at the base of the middle phalanx. The proximal interphalangeal joint is inflamed and contains an increased amount of fluid. The middle slip, which is a part of the capsule, becomes distended, and so does the triangular ligament, which holds the lateral slips together. The middle joint then becomes markedly flexed, following which the two lateral bands tear apart, being displaced volarward, thus allowing the joint to "herniate" (Fig. 3). In some patients trigger-finger action occurs in connection with this herniation when the lateral slips pass the broadest point of the finger. When this displacement has reached about the middle of the joint, the patient is no longer able to extend the middle phalanx. The lateral bands, which are now in tension, hold the distal phalanx in extension.

In the beginning stages, this deformity is reducible, and the middle phalanx can be passively extended, although the patient cannot hold it in this position. Later, when the lateral slips overlap and then become adherent to the collateral ligaments as a result of scarring, the deformity becomes irreducible and the proximal interphalangeal joints may fuse in the position of flexion. At a still later stage, the lateral slips may stretch out, allowing flexion of the distal interphalangeal joints. The patient will now have a pure flexion contracture of both interphalangeal joints. The metacarpophalangeal joints do not play

any role in the development of this deformity; they may have a normal range of motion or they may be in a position of flexion or extension. An individual with acute flexion deformity of the proximal interphalangeal joints, if he can use his fingers at all, can do so only by hyperextending the metacarpophalangeal joints. At this stage the condition resembles the claw-hand deformity mentioned by Steindler.

Different stages of development of the buttonhole deformity have been seen by us in fingers of the same patient.

FIG. 4
Buttonhole deformity of the thumb.

FIG. 5
Non-traumatic baseball-finger.

FIG. 6-A

FIG. 6-B
Bunnell's test for swan-neck deformity with intrinsic-plus factor.

Buttonhole Deformity of the Thumb

In the thumb, the anatomical relationships are different. Here the proximal phalanx is extended by the relatively weak extensor pollicis brevis, which is attached to the base of the phalanx, forming part of the fibrous capsule of the joint. The tendon of the adductor pollicis is attached to the ulnar side of the capsule, and the tendons of the flexor pollicis brevis and the abductor pollicis brevis are attached to the radial side. The strong tendon of the extensor pollicis longus passes the ulnar side of the dorsal aspect at this joint and is attached to the distal phalanx. In adduction of the thumb this tendon is always displaced some millimeters ulnarward. All of the forty-seven patients with buttonhole deformity of the thumb in our series had, or had had, severe inflammation of the first metacarpophalangeal joint. When a hand with this condition is used, the softened, inflamed capsule is further distended by the pull of the short muscles. Following this the tendon of the extensor pollicis brevis is stretched out and the tendon of the extensor pollicis longus is further displaced to the ulnar side with the result that the proximal phalanx cannot be extended. The distal phalanx is then pulled into a compensatory position of hyperextension

by the powerful extensor pollicis longus (Fig. 4). We did not include in our series the cases in which this deformity was of traumatic origin without inflammation of the joint.

Baseball-Finger

Ten patients in this series had non-traumatic baseball-finger as a result of inflammatory distension of the extensor digitorum communis which is attached to the base of the terminal phalanx (Fig. 5). Following distension of this tendon, its action was overpowered by that of the flexor digitorum profundus.

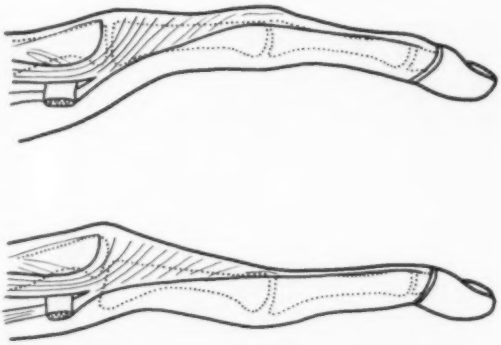

FIG. 7

Swan-Neck Deformity

Swan-neck deformity with hyperextension of the proximal interphalangeal joints and flexion of the metacarpophalangeal and distal interphalangeal joints, occurring as a result of intrinsic contracture, has been described by several authors as a typical rheumatoid lesion[3, 4, 5, 7].

In our series swan-neck deformity

FIG. 8-A

FIG. 8-B

Fig. 7: Volar displacement of the proximal phalanx with dorsal shift of the pull of the intrinsic muscles as a cause of the swan-neck deformity. The volar ligament of the metacarpophalangeal joint is distended distal to the transverse metacarpal ligaments.

Figs. 8-A and 8-B: A type of swan-neck deformity which disappears when the proximal phalanx is supported.

was present in forty-four patients, including twelve men, thirty women, and two children. This condition seems to be a deformity of the more advanced stages of rheumatoid disease. Only three of our patients had had the disease for less than two years.

There may be several different causes for this deformity. We have found that the following five causes may be clearly demonstrated:

1. Congenital ability to hyperextend the proximal interphalangeal joints. In our series, the "double-jointed" individuals with this ability were excluded.

2. Intrinsic-plus factor. The presence of contracture of the intrinsic muscles was determined by means of Bunnell's test [2] (Figs. 6-A and 6-B). We found this condition in its typical form in only two patients. The main difference between our series and the series reported by Bunnell in 1955 is probably that we had only a few cases in which the condition had reached the burnt-out stage, while Bunnell's series consisted exclusively of such cases.

FIG. 9-A

FIG. 9-B

Volar displacement of the proximal phalanges causes relaxation of the intrinsic muscles and the intrinsic phenomenon becomes negative.

3. Dorsal shift of the pull of the intrinsic muscle due to volar displacement of the proximal phalanges. We found that in every patient with this deformity the metacarpophalangeal joints were inflamed. There was volar displacement of the proximal phalanx, which could be determined by palpation and roentgenographic examination. When the proximal phalanx is displaced volarward, the interosseus and lumbrical tendons are held in their original places by the transverse metacarpal ligaments. Thus, the pull of the intrinsic muscles is directed more dorsally, causing hyperextension of the inflamed proximal interphalangeal joints. The tendon of the flexor digitorum profundus then automatically pulls the distal joint into flexion (Fig. 7). (In our series we never found any great amount of fluid in the proximal interphalangeal joints of these patients, contrary to our findings in patients with buttonhole deformity.) At a later stage, dislocation of the middle phalanx may develop, or the joint may fuse in the hyperextended position. In some of our patients this mechanism of the swan-neck deformity was well demonstrated in its beginning stages. If the basal phalanx was supported when the finger was extended, there was no deformity, but as soon as the basal phalanx was unsupported, it was immediately displaced volarward, and the typical deformity appeared (Figs. 8-A and 8-B).

Dorsal shift of the pull of the intrinsic muscles was the most common cause of the swan-neck deformity in our series. In uncomplicated conditions of this type there is no intrinsic contracture (Figs. 9-A and 9-B).

4. General fibrosis and shrinkage of the extensor apparatus in hands with "dry", adhesive, or rapidly stiffening rheumatoid conditions or with scleroderma. The deformation that results from these conditions resembles that appearing after burns on the dorsal side of the fingers. The proximal interphalangeal joints cannot be bent when the metacarpophalangeal joints are either flexed or extended (Fig. 10).

5. Deformity due to rheumatoid damage of the flexor digitorum sublimis. This was found only once, in a patient upon whom surgical exploration was done, but is probably present more often. A female patient with generalized rheumatoid arthritis first noticed snapping of the little finger in January 1954. There was a tender nodule at the volar side of the proximal interphalangeal joint. The flexion power of the finger diminished gradually, and after the snapping had ceased, in May 1954, the middle phalanx started to hyperextend. At operation in October 1954, the volar aspect of the capsule of the proximal interphalangeal joint and the adjacent tendon sheath were found to be oedematous, and a pea-sized nodule was removed from the flexor digitorum profundus. The radial slip of the flexor digitorum sublimis was thin, distended, and covered with a rheumatoid pannus, and there remained only a thread-like strand of the ulnar slip. The condition resembled exactly the end result of traumatic rupture of the superficial tendon near the phalangeal insertion [1].

FIG. 10

FIG. 11

Fig. 10: Rigid type of swan-neck deformity.

Fig. 11: Spontaneous rupture of the extensor pollicis longus tendon.

Spontaneous Rupture of the Tendon of the Extensor Pollicis Longus

In our series two men lacked the ability to actively extend the distal phalanx of the thumb as a result of spontaneous rupture of the extensor pollicis longus tendon (Fig. 11).

Rheumatoid granulomata of the tendons are not uncommon. They consist of (1) rheumatoid granulation tissue which has invaded the tendon fibers, (2) aggregations of lymphocytes and plasma cells, and (3) collagen fibers, which, when examined with an electron microscope, show a disintegration of the fibrils into an amorphous material [6]. It is no wonder that the tendon of the extensor pollicis longus, which has the most unfavorable course of all the tendons of the hand, easily ruptures in the presence of this lesion.

We have seen quite similar histological changes in the distended dorsal aspect of the capsules of the proximal and distal interphalangeal joints, as well as in the volar ligaments of the metacarpophalangeal and proximal interphalangeal joints. The only difference has been that in the ligaments degenerative rather than proliferative changes have been dominant.

Tendon Nodules

In our series rheumatoid nodules of the flexor tendons of the fingers were found in eight men and thirty-nine women. (In four men and ten women similar changes were present in the extensors, a location in which they do not cause any important dysfunction.) These changes may exist as an early sign of rheumatoid arthritis. In sixteen women, nodules of the flexor tendons were the cause of painful trigger-finger. In the total group, there was an amazingly high proportion of women.

Tendon nodules can grow to a considerable size, and we have several times removed from a tendon a granuloma that was the size of a bean. During the early stage of their development granulomata always produce snapping-finger, and after further growth they may cause flexion contracture of the finger or inability to clench the fist. In order to prevent permanent stiffening of the fingers, early active treatment of these nodules is advisable.

CONCLUSIONS

In this study, we have tried to clarify the role of rheumatoid lesions of the tendons and adjacent soft tissues in the development of finger deformities. Other factors, such as

loss of cartilage and bone substance, rheumatoid pannus formation, growth (in children), shrinkage as a result of scarring, bone fusion, way of using the hand, and pain, may also contribute to the development of the deformation. The most important factor, however, is the changes which occur in the tendons and related structures, especially in the early stages.

The primary factor seems to be the inflammatory softening and distension of the joint capsule. This is followed by loss of power in those muscles which are attached to the capsule, as a result of which the antagonistic muscles may pull the joint into a deformed position without causing any associated spasm. The type of deformity that results seems to be primarily determined by the anatomical conditions of the hand and the type of inflammation.

COMMENTS ON TREATMENT

Although we have not attempted to discuss the treatment of these deformities, we feel that a few remarks about local preventive measures should be given. Preventive measures should be directed against overstretching of the tendons and ligaments. It is very important to combat overdistension due to hydrops of the joint capsules by means of hydrocortisone. All strenuous manual labor and forcible physical therapy during the active stages of the disease, and all exercises which tend to overstretch the joints should be prohibited. Those joints having a tendency to become dislocated should be manually supported during exercises, and carefully individualized functional splinting is of great importance.

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The Spread of Soft-Tissue Sarcomata of the Extremities Along Peripheral-Nerve Trunks *

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The pathological relationship between sarcomata and the nervous system, including the possibility that sarcomata spread along the so-called perineural lymphatics, is a subject about which little has been written. For this reason it was determined to investigate this subject by means of an examination of amputated extremities. Accordingly, a study was made of all the cases of soft-tissue sarcoma of the extremities for which amputation had been performed at the Mayo Clinic during a given period. The nature and results of this study form the basis of this report.

HISTORICAL REVIEW

The authors' investigation was concerned primarily with the spread of sarcomata along peripheral-nerve trunks. In the past, the spread of carcinomata along nerve trunks has been described by many authors, including Ernst, Willis, and Jentzer; the subject has also been extensively reviewed by Drapiewski in his study on nerve involvement in carcinoma of the pancreas. In contrast, comparatively little has been written on sarcomatous invasion of the peripheral nerves.

Cruveilhier's report of a case of mammary carcinoma with invasion of the facial nerve is probably the first recorded instance of neoplastic involvement of peripheral nerves. He attributed the patient's extreme facial pain to the involvement of the nerve.

Le Tixerant and Broca, in 1847, reported a case of uterine carcinoma with extension into the sciatic nerve. The patient in this case had severe sciatic pain.

The first author to postulate that the neural spaces serve as channels for tumor metastasis was Ernst, in 1905. He reported several cases of carcinoma in which invasion of the nerves was a prominent feature and stated that in several investigations he had shown that the perineural spaces could be filled with injected dye. He felt that the spaces in the nerve trunk into which the carcinoma spread were pre-existing and were not formed by the invading tumor. He also felt that the tumor could extend beyond the limits of the invaded nerve. In some cases, he had noted that the invading tumor had a degenerative effect on the medullary sheath of the involved nerve. His observations were corroborated by Moscheowitz in 1914, Shattock in 1921, and Kaufmann in 1929.

Peet, in 1917, reported a case in which a spindle-cell sarcoma had originated in a "cavernous lymph and hemangioma" that completely engulfed the radial nerve. The nerve could not be traced in the excised gross specimen; yet the patient did not have wrist-drop until following the operation.

McGuire and Burden, in 1922, reported a case of a soft-tissue sarcoma of the forearm in which there was definite involvement of the median nerve. Necropsy had revealed a typical neurofibroma and, in some areas, spindle-cell sarcoma. Microscopic examination

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TABLE I

DISTRIBUTION OF TUMORS ACCORDING TO TYPE AND EXTREMITY AFFECTED

Diagnosis	Extremities		Total	Invasion of Nerves
	Upper	Lower		
Fibrosarcoma	24	30	54	7
Fibromyxosarcoma	5	11	16	1
Synovioma	3	6	9	3
Rhabdomyosarcoma	3	3	6	
Liposarcoma	1	5	6	
Myxosarcoma		4	4	
Spindle-cell sarcoma	1		1	
Benign myoblastoma		1	1	
Sarcoma, Grade 4		1	1	
Total	37	61	98	11

of the nerve trunk had disclosed marked fibrosis, atrophy of the nerve fibers, and marked infiltration by regular spindle cells with few mitotic figures.

In 1936, Meyerding, Broders, and Hargrave, in a review of fibrosarcomata, said that pain, either local or radiating, was a prominent feature in 36 per cent of their cases. They had found that referred pain, numbness, and partial and complete palsy were indicative of peripheral neuritis, a condition which had resulted from pressure on or actual invasion of the nerve and which had sometimes antedated the appearance of the tumor.

Willis, in 1952, noted that in some cases large nerves pass directly through tumors without becoming involved, remaining fully identifiable throughout their entire course. Earlier observations concerning this phenomenon were made by Cayley in 1868, by West in 1883, and by Hebert in 1918.

MATERIALS AND METHODS

As a basis for this study, all the pathological reports of sarcomata of the extremities treated at the Clinic were reviewed in order to select the cases of soft-tissue sarcoma in which amputation had been performed during the years 1904 to 1951 inclusive. Stout's classification [14] of soft-tissue sarcoma was used as a guide. One hundred and seventy-five cases, sixty of the upper extremity and 115 of the lower, were found. Following this all the cases of fibrosarcoma in which bone was involved (as determined by study of the surgical notes and the roentgenograms) and all the cases in which there were no gross specimens were excluded, which left ninety-eight cases for detailed study.

The clinical records of the ninety-eight cases were then summarized, and the amputated extremities were examined. The location, size, and gross characteristics of each tumor were recorded, and a block of tissue was removed for sectioning in order to confirm the original diagnosis.

The identifiable nerves were carefully removed, the dissection extending from the level of amputation to at least six or seven inches distal to the tumor when possible. The gross characteristics and length of

TABLE II

RELATIONSHIP OF TUMOR TO NERVE: GROSS FINDINGS *

Relationship		Cases
Not pathological		60
Pathological		38
Nerve was markedly displaced but not involved	4	
Nerve was firmly adherent but could be stripped from tumor and was not grossly involved	13	
Nerve passed through tumor but retained its identity; not enlarged or grossly involved	11	
Localized enlargement of nerve suggestive of invasion by tumor	6	
Diffuse enlargement of nerve suggestive of spreading of tumor into and along nerve	4	
Total		98

* Based on a study of 299 nerves from ninety-eight extremities.

TABLE III

RELATIONSHIP OF TUMOR TO NERVE: MICROSCOPIC FINDINGS

Relationship		Cases
Not pathological		87
Tumor not present	78	
Tumor adjacent to epineurium	9	
Pathological		11
Infiltration of epineurium	7	
Infiltration of epineurium and extension along nerve	4	
Total		98

the nerves under investigation were recorded. In general, if a nerve appeared to be involved in the malignant process, several blocks of tissue were removed for sectioning, these blocks being taken from the site of apparent involvement and from sites both distal and proximal (as far as the level of amputation) to the tumor. When a nerve appeared to be uninvolved by the malignant process, longitudinal sections were made in order to confirm this impression.

All available lymph nodes were examined grossly and microscopically for evidence of spread of the malignant process by way of the lymphatic channels.

RESULTS

Sixty-two of the patients were males and thirty-six were females. The oldest patient was seventy-four years old and the youngest was three, the average age being 43.7 years.

Thirty-seven of the sarcomata were located in the upper extremity and sixty-one, in the lower extremity. The distribution of the tumors according to type and extremity affected is given in Table I. This table also shows the types of sarcomata that invaded peripheral nerves, and the incidence of invasion.

The relationship of tumor and nerve, as observed grossly, is shown in Table II. The relationship was considered pathological in thirty-eight of the ninety-eight cases. In ten of these cases the gross findings suggested actual nerve involvement by the sarcomatous lesion.

The relationship of tumor and nerve, as observed microscopically, is shown in Table III. On the basis of this study, the relationship was considered pathological in only eleven of the ninety-eight cases. These eleven cases included the ten cases in which there was gross evidence of nerve involvement. The types of tumors that invaded the nerves were: fibrosarcoma, seven cases; synovioma, three cases; and fibromyxosarcoma, one case.

There were four sarcomata that had spread for some distance along the peripheral nerves. One of these four tumors had originated at the wrist and spread along the median nerve to the brachial plexus; one had originated in the calf and spread along the common peroneal-sciatic nerve to the site of amputation; and one had originated in the forearm and spread about two centimeters along the radial nerve. In the case of the fourth tumor, a synovioma of the forearm which had spread along the median and radial nerves, the specimen was not adequate for an estimate of the distance of spread.

Complaints that would indicate the presence of a pathological relationship between the tumor and nerve had been made by fifty patients. These complaints included: pain, forty-seven patients; numbness, six; weakness and palsy, six; neuritis, two; and paraesthesia, one. In only twenty-three of the cases, however, could the complaints be explained on the basis of the findings of gross and microscopic study. The findings of these studies included: adherence of the nerve to the tumor, ten patients; invasion of the nerve by the tumor, nine; displacement of the nerve by the tumor, three; and passage of the nerve through the tumor, one. Of the eleven patients in whom definite microscopic evidence of invasion of a nerve by the tumor had been found, six had had pain, one had had numbness, and one had had pain and numbness, while three had had no discomfort at all.

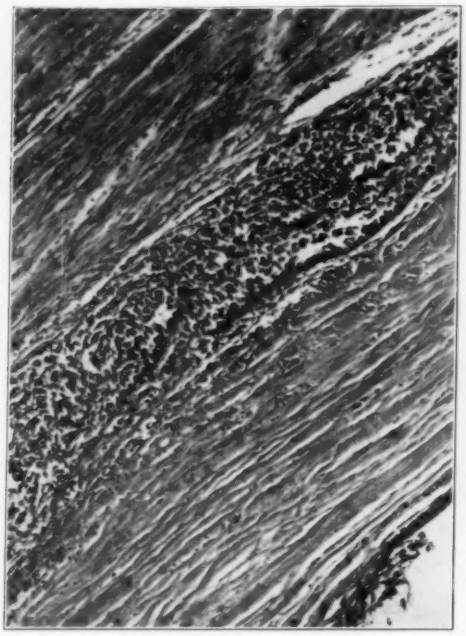

FIG. 1-A

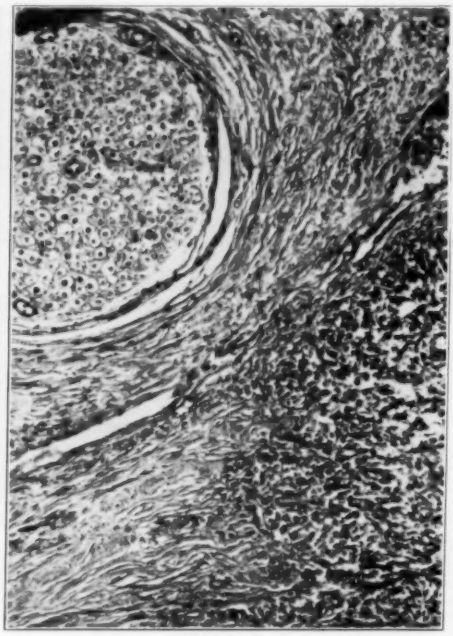

FIG. 1-B

Fig. 1-A: Longitudinal section of the radial nerve. Synovioma cells have infiltrated the spaces among the nerve bundles in the epineural connective tissue (hematoxylin and eosin; × 100).

Fig. 1-B: Cross section of the median nerve illustrating infiltration of the epineural connective tissue by the synovioma. The perineurium has not been invaded, and the nerve bundle appears normal (hematoxylin and eosin; × 100).

Regional lymph nodes were present in only ten specimens, none of which contained tumor cells. Review of the case records indicated, however, that metastasis to nodes had occurred in twelve of the patients.

The four cases in which the tumor had apparently spread along peripheral-nerve trunks are reported in the following section.

CASE 1. A man, forty-two years old, first noted a mass in the upper part of his left forearm in July 1914. The mass subsequently became painful. Excision was done in March 1915, but apparently not all of the mass could be removed. A diagnosis of round-cell sarcoma was made. The mass recurred and amputation was performed through the upper one-third of the arm in September 1915.

The gross specimen was a firm, poorly circumscribed mass. The ulnar and radial nerves were definitely enlarged at several sites, and microscopic examination revealed the presence of a tumor in the perineural connective tissue. Since only part of the specimen was available at the time of the authors' study, the distance the tumor had actually spread along the nerve could not be determined. Examination of new microscopic slides revealed that the tumor was a synovioma (Figs. 1-A and 1-B).

CASE 2. A dentist bought a hand fluoroscope in 1917, when he was thirty-four years old. In 1922, a rash developed on his left hand, and in 1938, a sore that would not heal developed on the long finger of that hand. Although biopsy disclosed that the lesion was benign, the finger was amputated because of pain. In 1942, a growth developed on the index finger of the left hand. Biopsy revealed a sarcoma, Grade 2, and part of the finger was amputated. From this time on, the patient had neuritic pain in the left palm and phantom pain in the remnants of the amputated fingers. In 1949, the tumor recurred in the stump of the index finger; the stump was therefore removed. Despite this treatment, however, the pain in the hand became severe and continuous. By April 1950, when he was sixty-seven years old, the patient had a fixed mass on the volar aspect of the wrist, and biopsy disclosed fibromyxosarcoma, Grade 3. Amputation was performed through the middle third of the left arm. Examination of the gross specimen revealed that the median nerve was enlarged and that tumor tissue extended throughout the nerve, up to the site of amputation. One week

FIG. 2-A

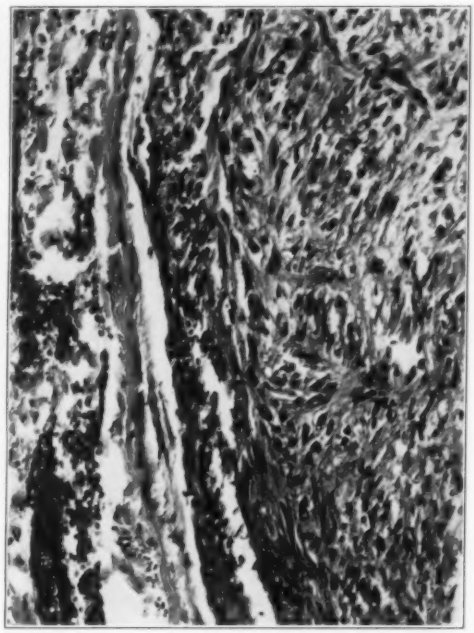

FIG. 2-B

Fig. 2-A: Cross section of the median nerve showing replacement of the nerve bundles by neurogenic sarcoma cells (hematoxylin and eosin; × 30).

Fig. 2-B: Cross section of the median nerve showing more cell detail. The nerve bundle has been completely replaced by the neurogenic sarcoma (hematoxylin and eosin; × 200).

later, the remaining portion of the median nerve was excised as far as the brachial plexus. Microscopic examination revealed that tumor cells had invaded this entire nerve except for a portion about 2.5 centimeters long, just distal to the junction of the nerve with the brachial plexus.

Recent microscopic study of the tumor cells in the median nerve revealed that the nerve bundles themselves were replaced by spindle cells arranged in a whorled and palisaded manner; on the basis of this finding it was thought that the tumor might be a neurogenic sarcoma (Figs. 2-A and 2-B).

CASE 3. A man had a mass in the calf of the left leg. This mass was excised in 1937, when he was thirty-one years old, but later recurred. It was again excised in 1941, after which x-ray treatment was given. The mass recurred a second time, accompanied by numbness in the sole of the foot. Amputation was performed in June 1943, when the patient was thirty-seven. The diagnosis was fibrosarcoma, Grade 4.

Gross examination of the specimen revealed a large, solid mass. The sciatic, common peroneal, deep peroneal, and tibial nerves were all about twice their normal size. Microscopically, it was seen that the tumor had invaded the epineural connective tissue as far as the site of amputation (Fig. 3).

Case 4. A mass developed in the region of the right elbow of a forty-three-year-old man in February 1951. In March this mass was excised, and a diagnosis of fibrosarcoma, Grade 3, was made. Following biopsy, wrist-drop developed. In May 1951, disarticulation of the right shoulder was done.

In the gross specimen a solid infiltrating mass that involved the triceps and extensor muscles of the forearm was found on the radial side of the elbow. It was seen that, at the elbow, the radial nerve was enlarged to a diameter of one centimeter for a distance of four centimeters. In places this nerve coursed through the tumor. Microscopic examination revealed that there was almost complete invasion of the epineural connective tissue in the region of the tumor but that there was no invasion beyond this region (Figs. 4-A and 4-B).

SUMMARY AND CONCLUSIONS

In thirty-eight of ninety-eight amputated extremities, the following evidence of a

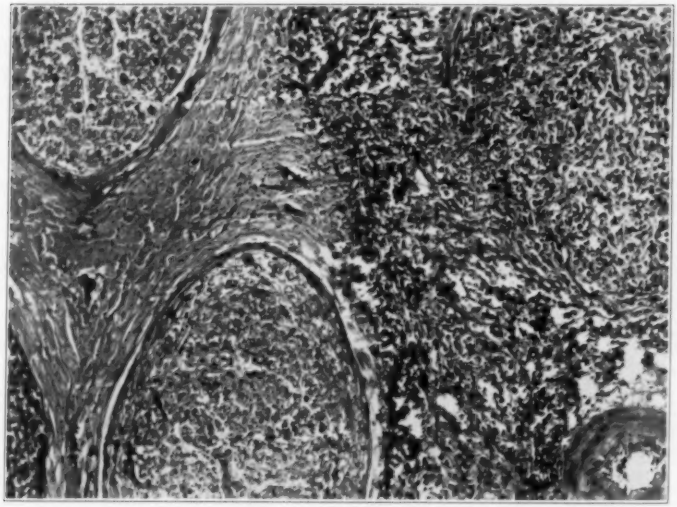

FIG. 3

Cross section of the tibial nerve illustrating infiltration of the spaces between the nerve bundles by a fibrosarcoma, Grade 4. The perineurium has not been invaded (hematoxylin and eosin; × 75).

FIG. 4-A

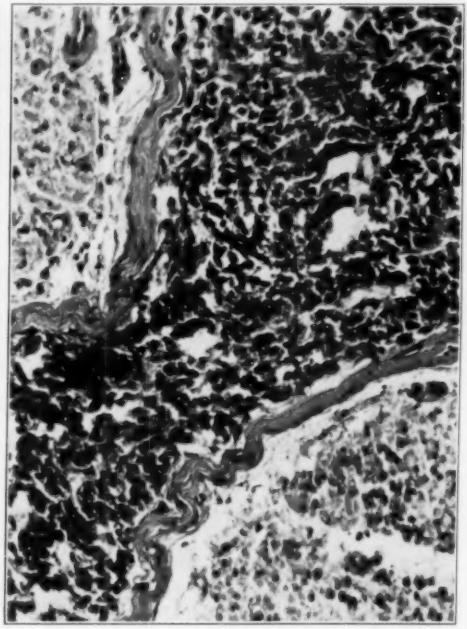

FIG. 4-B

Fig. 4-A: Cross section of the radial nerve illustrating infiltration of the space between two nerve bundles by fibrosarcoma, Grade 3. The nerve bundles appear to be intact (hematoxylin and eosin; × 50).

Fig. 4-B: High-power photomicrograph of a cross section at the radial nerve (hematoxylin and eosin; × 200).

pathological relationship between sarcomata and peripheral nerves was found: adherence of the nerve to the tumor, thirteen cases; displacement of the nerve by the tumor, four cases; passage of the nerve through the tumor, eleven cases; and invasion of the nerve by the tumor, ten cases. Microscopic study revealed that the tumor had infiltrated the epineurium in seven extremities and that it had infiltrated the epineurium and spread along the nerve in the epineural connective tissue for varying distances in four extremities. Thus, in eleven of ninety-eight extremities the tumor had invaded peripheral nerves. Metastasis to the regional lymph nodes had occurred in twelve of the extremities (as evidenced by the case records alone).

Fifty of the ninety-eight patients had complained of neurological symptoms, such as pain or numbness, but in only twenty-three instances was it possible to explain these complaints on the basis of gross and microscopic findings.

The results of this study suggest the following conclusions:

1. Invasion of peripheral nerves by soft-tissue sarcomata of the extremities is fairly common.

2. Invasion of peripheral nerves by soft-tissue sarcomata seems to be confined mainly to the epineural connective tissue; the nerve bundles and the perineurium apparently resist invasion.

3. Soft-tissue sarcomata that invade the epineural connective tissue of peripheral nerves may spread along this tissue.

4. In cases in which there is pathological involvement of the peripheral nerve by a soft-tissue sarcoma, there may or may not be associated symptoms and signs.

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Low Lumbar Nerve-Root Compression and Adequate Operative Exposure

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The purpose of this paper is to discuss the low-lumbar foraminal areas and their bearing on the surgery of sciatica.

The key structure in the surgical anatomy at the fifth lumbar-disc level, apart from the disc itself, is the articular process of the sacrum. This structure is important for two reasons: first, because of its relationship to the first sacral and fifth lumbar nerves (Figs. 1 and 2) with the possibility of direct or indirect compression of these nerves, and second, because the space relationship at the level of the fifth lumbar disc between the articular process behind and the fifth lumbar vertebral body in front may create certain technical problems for the surgeon.

In a previous article we described a lateral bony recess of the spinal canal at the fifth lumbar-disc level. This recess is bounded in front by the fifth lumbar disc and vertebral body and behind by the medial portion of the articular process of the sacrum which lies in the frontal plane. In many instances, when the fifth lumbar disc degenerates and becomes thinned, the fifth lumbar vertebral body not only descends, but a backward dis-

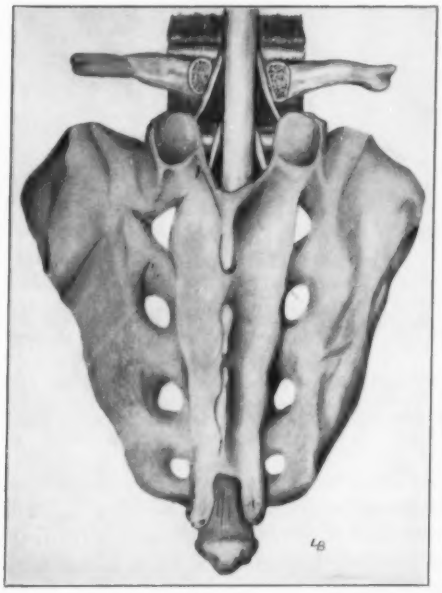

FIG. 1

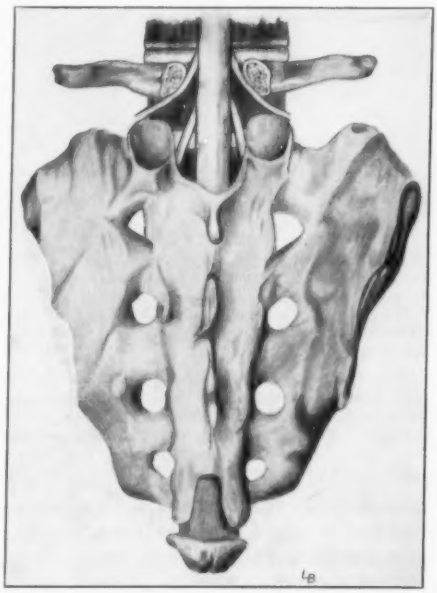

FIG. 2

Fig. 1: Semidiagrammatic drawing, showing the spinal canal from behind with the laminae and inferior articular processes of the fifth lumbar vertebra removed. The fifth lumbar nerve can be seen entering the recess between the articular process of the sacrum and the body of the fifth lumbar vertebra on each side.

Fig. 2: Similar view of the spinal canal. In this instance the fifth lumbar nerves do not enter the recess, but make their exit from the foramen in a more transverse direction above the articular process of the sacrum.

placement of the vertebral body also takes place, because of the normal posterior inclination of the articular processes. The lateral recess then becomes contracted from before, backward (Figs. 3, 4, 5, 6, and 7). Our earlier article described two cases in which the first sacral nerve had become incarcerated in the lateral recess and sciatica had resulted.

FACETECTOMY

A number of authors have recommended removal of the articular processes for the relief of sciatica, usually when exploration of the spinal canal was negative and when probing indicated the likelihood of bony encroachment into the foramen. Facetectomies

FIG. 3

FIG. 4

Fig. 3. Roentgenogram of hemisected cadaver spine. The fifth lumbar disc has almost completely collapsed and the articular process of the sacrum is actually in contact with the body of the fifth lumbar vertebra so that the lateral recess is obliterated at that point.

However, in this instance neither the first sacral nor the fifth lumbar nerve was compressed in the recess since the fifth lumbar nerve made its exit above the articular process of the sacrum and the first nerve lay medial to it.

Fig. 4. Roentgenogram of a sagittal slice made through the lateral recess of a cadaver spine. The fifth lumbar disc is thinned and the articular process of the sacrum impinges against the pedicle of the fifth lumbar vertebra. However, in this instance the lateral recess is not contracted from before backward and there is ample space for the nerve passage.

have been indicated also when previous surgery failed to relieve sciatica, when roentgenograms showed evidence of arthritis of the apophyseal joints, and when collapse of the disc space had occurred. The operation was first reported in 1927 by Putti, and, according to Gray, was elaborated and used extensively by Bankart. Reports on series of facetectomies have been presented by Briggs and Krause, Crawford, Mitchell and Granger, Hirsch, Hyndman, and Gray.

These authors have described disc herniation into the foraminal canal, contraction of the foraminal space secondary to flattening of the disc, hypertrophic lipping of a vertebral body, bulging of the ligamentum flavum, and arthritis of the apophyseal joints.

The following case reports are presented to illustrate certain surgical implications of the bony relations of the low lumbar spine.

CATEGORY I. HERNIATIONS OF THE DISC WITHIN THE LATERAL RECESS
(Fifteen Cases) *

CASE 1. A. D., a mechanic, thirty-eight years old, since sustaining a fall in 1940, had complained of severe pain in the low back, in the back of the left thigh, and occasionally in the left calf. Three weeks before operation the pain had become so excruciating that the patient had been crippled. The examination showed a mildly positive straight-leg-raising test of the left limb. Flexibility of the lumbosacral spine was good, with pain over the low back when hyperextension was forced. The examination otherwise was not noteworthy. Roentgenograms of the lumbosacral spine showed almost complete collapse of the fifth lumbar disc with the articular process of the sacrum subluxated upward and apparently wedged into the pedicle of the fifth lumbar vertebra.

At operation on September 18, 1954, the left first sacral nerve was found to pursue a more oblique course than is usual. When the nerve was retracted medially, it was found to be adherent below so that only its upper portion could be retracted. The nerve was noticeably angulated. No herniation of the disc could be seen in the spinal canal. The margin of the fifth lumbar lamina and the inferior articular process on the left was removed with a gouge, exposing the medial portion of the sacral articular process. This was removed, exposing a moderate-sized protrusion of the fifth lumbar disc. The annulus was incised and two large sections of degenerated material came away readily. The first sacral nerve was then found to retract quite normally without angulation. The disc space was thinned.

The results were excellent. The patient returned to work about three weeks after the operation and has remained symptom-free. The ankle jerk which was absent after the operation had not reappeared at the patient's last follow-up examination on August 7, 1956. Sensation and power in the lower extremities were normal. The back showed normal flexibility and the straight-leg-raising test was negative on both the right and the left sides.

In this patient, the herniation of the fifth lumbar disc had taken place in the lateral recess. The herniation was of the dissecting type and the first sacral nerve had become adherent to the herniation inferior to the level of the disc. The clue to the herniation in the lateral recess was the indirect evidence given by the angulation of the first sacral nerve when the attempt was made to retract it medially.

FIG. 5

Fig. 5: Roentgenogram of a hemisected cadaver spine. The fifth lumbar and the second lumbar discs have completely collapsed. At the fifth lumbar-disc level, the articular process of the sacrum is almost in contact with the pedicle of the fifth lumbar vertebra above and is almost in contact with the body of the fifth lumbar vertebra in front.

CATEGORY II. HERNIATIONS OF THE DISC WITHIN THE FORAMEN
(Fifteen Cases)

Several observers in isolated instances have found disc herniation with nerve-root compression in the foramen at surgery. Lindblom, in a pathological study, found the condition to be quite common. He removed and dissected the lumbosacral spine in 160 routine autopsies of patients from fourteen to eighty-seven years of age. Macroscopic evidence of nerve-root compression was found in sixty instances, mainly by dorsolateral disc protrusions. The usual site of compression was the ganglion or the spinal nerve distal to it. Subsequently Lindblom and Rexed carried out a histological study of the spinal nerves concerned in these cases and found evidence of nerve degeneration, either

* The figures quoted are from the combined surgical experience of 689 lumbar disc explorations recorded at The New Jersey Orthopaedic Hospital and The Glens Falls Hospital.

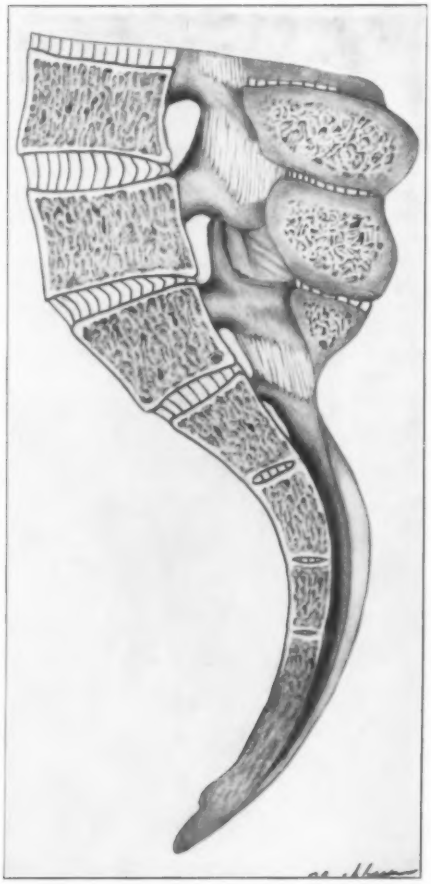

FIG. 6

FIG. 7

Fig. 6: Drawing of a hemisected spine viewed from within outward. The ligamentum flavum has been removed from the articular processes at the level of the fifth lumbar vertebra and sacrum. The articular process of the sacrum is impinging against the pedicle of the fifth lumbar vertebra. The posterior relations of the foraminal canal have been altered, and the articular process of the sacrum has become the posterior wall of the entire lateral paraspinal area.

Fig. 7: Photograph of a hemisected cadaver spine viewed from within outward. The lateral recesses and foraminal canals at the three levels seen are all contracted, especially at the level of the fourth lumbar disc. It should be noted that the marked contraction of the foramen and recess at this level is not due to bone hypertrophy nor to enlargement of the ligamentum flavum, but to the subluxation of the superior articular process of the fifth lumbar vertebra. This process, covered by ligamentum flavum, appears to be impinging not only against the fourth lumbar pedicle above but also against the fifth lumbar disc in front and is practically obliterating the lateral recess.

Incidentally, the posterior portions of the discs have all but disappeared. This type of appearance bears out the contention of Lindblom and Hultqvist that healing of the degenerated disc takes place more by absorption than by fibrosis.

recent or of long standing. Lindblom obtained a history of backache and sciatica in a large percentage of cases and correlated the anatomical finding of nerve-root compression with back and sciatic pain.

The extremely high incidence of nerve-root compression caused by disc herniation observed in these studies is in striking contrast to the low incidence of disc herniation in studies such as those conducted by Horwitz which were based on cadaver spines from the anatomy laboratory. A possible reason for the discrepancy in these observations may be

the difference in the anatomical material studied. The usual anatomical specimen is that of an old or aged man, whereas the spines sectioned by Lindblom were removed at autopsy from patients of widely varying ages. There is no doubt that at least some of his material is analogous to clinical material observed at the operating table.

In conditions of advanced disc degeneration, we have commonly observed a generalized, ridge-like, posterior projection of the annulus fibrosus, or a hypertrophic lip of the adjoining vertebral body; the exiting nerve had frequently accommodated itself to the projection and, in some instances, had become adherent to it. (See Figure 8 for possible early stage of such a lesion.) We have paid little attention to these findings when dissecting cadavera since they do not resemble the disc herniations seen at operation and have seemed unimpressive. However, Lindblom's studies would indicate that such lesions are probably productive of symptoms. There may be speculation as to what extent the nerve compression and nerve degeneration found in the high percentage of cases reported by Lindblom can be considered causative of really severe sciatica. This is a legitimate speculation, since with very few exceptions surgery has revealed disc protrusion with nerve compression in either the spinal canal proper or very close to it. It has seldom been necessary to continue the exploration into the region of the spinal ganglion or the spinal nerve distal to it.

FIG. 8

Fig. 8: Roentgenogram of a hemisected cadaver spine showing thinning and degeneration of the fourth and fifth lumbar discs. At the fourth lumbar-disc level the thinned posterior portion of the annulus fibrosus appears to be somewhat redundant and is bulging into the spinal canal. At the fifth disc level the articular process of the sacrum has subluxated upward and the articular process is now the entire posterior wall of the foraminal canal and recess.

CATEGORY III
(Eight Cases) *

The fifth lumbar and the first sacral nerves may be compressed against the fifth lumbar disc and vertebral body by the articular process of the sacrum, even in the absence of herniation of the fifth lumbar disc.

CASE 2. W. E. W., a road construction laborer, forty-nine years old, three years before examination had begun to complain of an aching and burning pain in the posterior portion of the left thigh. The pain became much more persistent in May 1953, extending down the outer aspect of the left lower extremity to the ankle. Since that time he had never been completely free of pain. He took a considerable amount of opiates during this period and he had been unable to work since May 1953, although he had attempted to. He had been admitted to a university hospital on three separate occasions during 1953, for physical therapy, traction, and myelography, which proved to be negative.

On examination, there was no deformity of the spine. Forward flexion was somewhat restricted with complaint of pain in the lower part of the left buttock. Straight-leg raising was moderately restricted on the left side with complaint of pain in the low back in the mid-line. The right side was normal. Neurological examination of the lower extremities showed nothing exceptional.

* We have operated upon six other patients with contracted lateral recesses without definite evidence of nerve compression.

Roentgenograms of the lumbosacral spine revealed the presence of a few droplets of pantopaque in the spinal canal. The fifth lumbar disc appeared to be narrowed posteriorly and the remaining disc spaces were of normal height. There was no evidence of arthritis. The lumbosacral joint showed an acute angle.

Despite a negative myelogram, this patient was operated upon June 26, 1954. The fifth lumbar interspace on the left side was entered. The first sacral nerve lay under the border of the dura, medially. The spinal canal appeared to be open, without adhesions, and with no evidence of a disc protrusion. However, the articular process of the sacrum on the left side was found to be displaced anteriorly, so that it was practically apposed to the body of the fifth lumbar vertebra. The fourth disc space on the left side was then cleared, and the fifth lumbar nerve and the disc were exposed; they appeared to be normal.

The fifth intervertebral space was again entered and the inferior articular process of the fifth lumbar vertebra was removed at its base. This exposed the full extent of the sacral articular process which was removed to its base. In order to do this with safety, the articular process was pried backward, away from the body of the fifth lumbar vertebra with which it was practically in contact. The fifth lumbar nerve did not appear to be abnormal, although it had been in contact with the articular process of the sacrum. A Hibbs spine fusion was carried out on the right side.

Postoperatively, the sciatica disappeared promptly and did not recur. The left ankle jerk was absent and sensation in the lower extremities was normal. The patient was discharged wearing a brace. At his last examination, April 6, 1955, he was no longer wearing the brace and stated that he had had no sciatica since the operation. He complained of occasional mild backache in wet weather or on excessive exertion. He was working as a building custodian, operating an elevator, cleaning offices, sweeping, mopping, and carrying pails of water. The spine showed a normal range of motion for the patient's age and body build. Minimal tenderness was present over the fifth lumbar vertebra. The deep reflexes were normal. There was minimal impairment of sensation on the lateral aspect of the left limb. Straight-leg raising was negative on both sides.

In this patient, the lateral recess was found at operation to be almost completely obliterated. However, the first sacral nerve lay medially and in no relationship to the articular process of the sacrum. The fifth lumbar nerve passed obliquely through the upper portion of the lateral recess and was pinched between its anterior and posterior walls, which were almost in contact. There was no evidence of a disc protrusion at either the fourth or the fifth lumbar disc levels.

When the lateral recess is contracted and the fifth lumbar nerve is compressed, extreme caution should be observed in removing the sacral articular process. The maneuver of prying the process away from the fifth lumbar vertebra provides a certain degree of safety. In an operation in which this precaution was not taken, the fifth lumbar nerve was traumatized and causalgia resulted.

HYPERTROPHY OF BONE AND NERVE-ROOT COMPRESSION

In an interesting and searching article, Echols and Rehfeldt reviewed 149 operations for sciatica; in thirty-two, no disc herniation was found. The authors considered that there were negative results in only fourteen of these explorations. In the remaining eighteen explorations, various conditions were found which were considered to be adequate to cause sciatica. In this group there were four patients in whom the nerve root "was found to be compressed by an apparent overgrowth of bone with resulting narrowing of the intervertebral foramen". In each instance, "the root was decompressed by facetectomy".

The authors stated that "although hypertrophy of bone is a somewhat vague explanation for sciatica, the lesions were convincing and the follow-up study tends to verify the diagnosis". At The New Jersey Orthopaedic Hospital a few similar operative diagnoses have been made.

Some of the instances of nerve compression described by these authors may in reality have been due to subluxation of the articular processes. In dissections of cadavera several causes of bony encroachment in the spinal canal and the foraminal areas have been found:

1. A hypertrophic rim of one of the two opposing posterior borders of the involved vertebrae may extend to some degree over a ridge-like bulge in the disc;

2. Backward displacement of the superjacent vertebra may create a posterior ridge at the inferior border of its vertebral body;

3. Upward and anterior subluxation of the superior articular process of the subjacent

vertebra can cause contraction of the foraminal canal and of the lateral recess in the lateral plane (Fig. 7).

In patients in whom the superior articular process actually has been in contact with the pedicle of the vertebra above, a spur may project anteriorly from the upper border of the articular process, making it a weight-bearing structure. Such a spur, however, does not materially diminish the foraminal space (Fig. 9). The usual hypertrophic changes in the articular processes take place posteriorly in relation to the apophyseal joint and do not of themselves cause diminution of the foramen or of the lateral recess. Occasionally, there may be seen a spur extending medially from the superior articular process which has the effect of extending the lateral recess in this direction (Fig. 10).

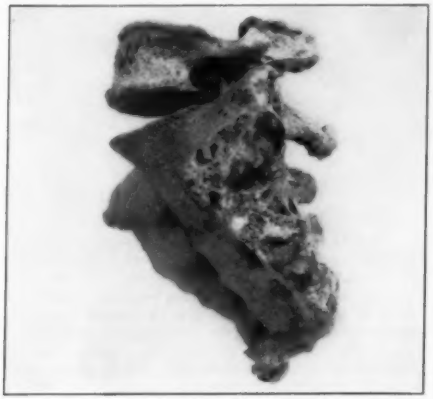

FIG. 9

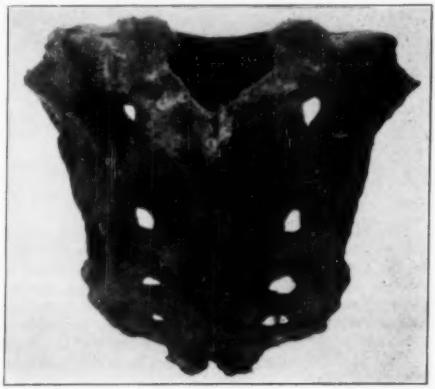

FIG. 10

Fig. 9. Articulated but slightly separated fifth lumbar vertebra and sacrum, showing the articular process of the sacrum with a large spur extending forward from the superior border. In this case, the spur was a true weight-bearing process and a facet had formed on the inferior surface of the pedicle of the fifth lumbar vertebra which articulated with the spur.

Fig. 10. Photograph of sacrum from behind showing a large spur extending medially from the medial border of the left sacral articular process. Such a spur would have the effect of extending the posterior wall of the lateral recess in the medial direction.

CATEGORY IV
(Five Cases)

Not infrequently, in old degenerative lesions of the fifth lumbar disc, the lamina of the sacrum rides upward, diminishing the space between the fifth lumbar body and the sacral lamina. In patients in whom the first sacral nerve has been pressed near or against the lamina of the sacrum by an underlying disc protrusion (Fig. 12), it is advisable to remove a portion of the sacral lamina.

CASE 3. Mrs. M. C., a housewife, fifty-six years old, had had recurrent pain in the left buttock for twenty years. For six years prior to surgery she had had continuous radiating pain down the posterolateral aspect of the left thigh and leg to the heel. She complained that she had difficulty in walking "because the leg tired" and that she was unable to bear weight on the ball of the left foot when walking upstairs.

The examination revealed a healthy, normally nourished woman. The spine did not appear to be deformed. Point tenderness of mild degree was present over the lumbosacral interspace in the mid-line and there was tenderness over the left greater sciatic notch. Straight-leg raising on both sides was possible almost to 90 degrees. On the left side, the patient complained of tightness of the hamstrings. The right ankle jerk was normal. The left ankle jerk was absent even on reinforcement. Sensory impairment was noted over the posterolateral aspect of the left leg. The triceps surae in the left lower extremity was weak and the patient was unable to stand on the ball of the left foot when she raised the right foot from the floor. There was obvious atrophy of the left calf; it was approximately three-fourths of an inch smaller in circumference than the right calf.

FIG. 11-A

FIG. 11-B

Fig. 11-A: Photograph of articulated fifth lumbar vertebra and sacrum. There is a large spur extending downward from the inferior articular process of the fifth lumbar vertebra and fitting into a saddle defect in the lamina of the sacrum. (This has been described by Badgley.) The apparent hole in the fifth lumbar vertebra on the left above was due to the formation of a large hypertrophic bridge which had grown from the junction of transverse process and pedicle to the inferior articular process of the fifth lumbar vertebra. When the fifth lumbar vertebra and sacrum were articulated, the upper portion of the articular process of the sacrum fitted into the hole.

Fig. 11-B: Photograph of the same fifth lumbar vertebra from below, revealing the hypertrophic bridge of bone.

Roentgenograms of the lumbosacral spine revealed generalized osteo-arthritic changes in the lumbar spine. There were six lumbar vertebrae, the sixth being of the sacral type. The fifth and sixth lumbar discs appeared narrowed with some backward displacement of the fifth lumbar vertebra on the sixth lumbar vertebra. The fourth lumbar disc appeared narrowed on the right side with almost complete bridging, laterally, on the left side.

The patient was operated upon August 29, 1952. When the space between the fifth and sixth lumbar vertebrae was exposed, the left first sacral nerve was found to be crushed against the lamina of the sixth lumbar vertebra. The nerve was retracted medially with difficulty from an underlying hard, small, adherent disc protrusion. This was incised and removed together with a small amount of degenerated material which remained in the narrow disc space. The space under the sixth lumbar lamina was found to be contracted by the backward displacement of the body of the fifth lumbar vertebra in relation to the sixth lumbar vertebral body. Because of this, a further section of the sixth lumbar lamina was removed.

Postoperatively, the sciatic pain disappeared promptly. Sensory impairment over the left limb diminished but the left ankle jerk was absent. At the last follow-up examination on August 8, 1956, the patient stated that she had had no pain in the back or in the left lower extremity, and that she had been quite active. The lumbosacral spine showed a normal range of motion for the patient's age. She walked without a limp. Her left calf showed no obvious atrophy and its circumference was one-sixteenth of an inch less than her right calf. However, the left triceps surae was still weak. Sensation in the left lower extremity was normal. The left ankle jerk continued to be absent.

CATEGORY V
(Six Cases)

Occasionally, large herniations are found to extend from the spinal canal into the lateral recess. In order to retract the overlying nerve with safety and to remove the disc adequately, a portion of the articular processes should be removed (Fig. 13).

Case 4. N. C., a man, fifty-five years old, employed as a motion picture projectionist, had had a catch or "kink" in his lower back about nine weeks before examination and had been momentarily unable to straighten up. Since that time he had had an aching pain in the left lower back with recurrence of the "kink".

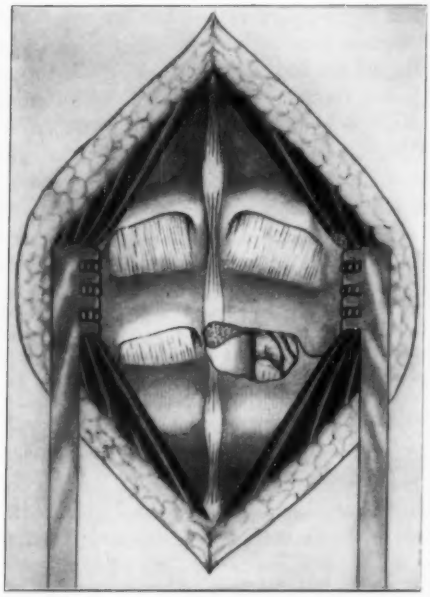

FIG. 12

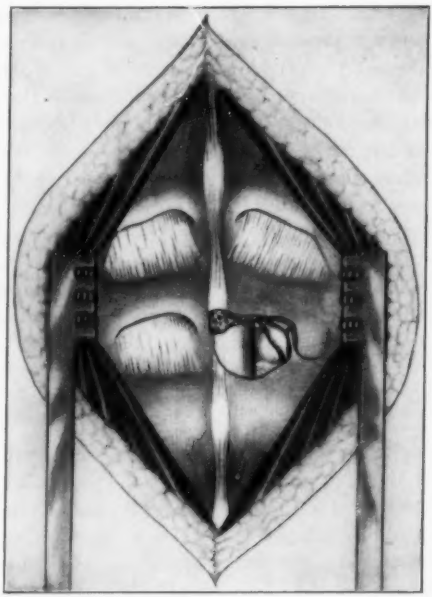

FIG. 13

Fig. 12: Semidiagrammatic drawing showing an operative exposure of the fifth lumbar interspace on the right. A large herniation of the fifth lumbar disc projects backward and inferiorly, pressing the flattened first sacral nerve over it and bringing the nerve in proximity to the lamina of the sacrum.

Fig. 13: A semidiagrammatic drawing showing an operative exposure of the fifth lumbar interspace on the right. A disc herniation can be seen with the flattened first sacral nerve pressed backward and laterally by the herniation against the articular process of the sacrum.

About two weeks after the onset of the condition, he complained of pain radiating down the left buttock, the posterior portion of the thigh, and the outer aspect of the left calf. This pain had returned intermittently, and for approximately six weeks before examination the patient had experienced severe sporadic pain when standing. About a dozen physical therapy treatments, including intermittent traction, had been given without relief. There was a history of "lame back" with occasional mild pain for five years, but there had been no sciatica until the present attack.

On examination, forward flexion was considerably restricted. Straight-leg raising on the left side was mildly restricted with complaint of pain in the left lower back. The neurological examination of the lower extremities was negative. Roentgenograms of the lumbosacral spine revealed that the fifth lumbar transverse process on the right side was of the sacral type with evident attachment to the ala of the sacrum. The lowest functioning disc, therefore, was the fourth lumbar. This was moderately thinned and there was considerable backward displacement of the fourth lumbar vertebral body on the fifth.

At operation on December 2, 1954, the fourth lumbar interspace on the left side was exposed. The dura was found to be compressed by ligamentum flavum and there was a deep transverse depression across the dura at the upper portion of the interspace. On palpation, the dural sac felt "doughy". The ligamentum flavum attached to the medial border of the fifth lumbar superior articular process on the left was found to be in contact with and slightly adherent to the flattened fifth lumbar nerve. This portion of ligament felt stiff and hard, and it was rather thick. A section of the superior articular process on the left side was removed; after this was done it was easy to approach the nerve and the herniation underneath. The herniation was ridge-like, and it was the full height of the fourth lumbar disc on the left side, extending practically from the mid-line far into the lateral recess. (This resembled the squashed disc described by Harris and Macnab.) After the nerve was retracted, the annulus was incised in a rectangular manner. Sequestrated nucleus was extruded under pressure. A large amount of disc material was removed.

Postoperatively, the sciatica cleared up promptly. Neurological examinations continued to be negative. At the patient's last follow-up examination on August 9, 1956, he stated that sciatica had not recurred but that he had "soreness" in the low back after such activities as shoveling snow or excessive bending. He also complained of numbness on the outer side of the left leg when he became tired. Neurologically, the lower extremities were normal and flexibility of the spine was within normal limits.

In this patient, the fifth lumbar nerve was not in the lateral recess, but lay close to it; it was compressed against the stiff ligamentum flavum attached to the superior articular process of the fifth lumbar vertebra. The herniation extended deep into the lateral recess. It was necessary to remove a portion of the superior articular process of the fifth lumbar vertebra in order to approach the fifth lumbar nerve from the lateral side with safety, since the nerve was squeezed against the stiff ligamentum flavum and was adherent to it. Finding the dura compressed posteriorly by ligamentum flavum was of interest. We believe that this was caused not by hypertrophy of the ligamentum flavum, but by the disturbance of the relations of the articular processes which produced a forward displacement of the fifth lumbar articular process in relation to the fourth lumbar body, pulling the ligamentum flavum forward against the posterior aspect of the dura. This was the cause of the deep transverse depression noted on examination. The "doughy" feeling of the dural sac, noted on palpation, was caused by much of the spinal fluid having been pressed out of the area.

THE DIAGNOSTIC TAP TEST

Briggs and Keats described a diagnostic tap test in two cases in which the fifth lumbar nerve had been compressed in the foramen by a lateral herniation of the fifth lumbar disc. This test was the outcome of a chance observation at the operating table. The authors noticed a violent contraction of a patient's glutei as the osteotome was driven against the fifth lumbar inferior articular process in preparation for spine fusion. We have observed this reaction in several of our own operations and have found that the impulse of the tap is transmitted to the vertebra below, producing the reflex movement described. When this reflex gluteal contraction is present, we believe one can infer not only that the involved spinal nerve is being pinched between the supporting structures, but also that it is being pressed against bone — the pedicle, the lamina, or the articular process, possibly with ligamentum flavum intervening. When this reflex gluteal contraction occurs, the surgeon should be alerted to possible marked posterior displacement of the nerve and should use extreme care on entering the spinal canal. A second implication of a positive tap test is indicated by Briggs and Keats in their report. In the absence of positive findings in the spinal canal at the two lowest lumbar disc levels, compression of the exiting spinal nerve against the pedicle or the articular process in the foraminal area may be anticipated. Thus, a positive tap test in the presence of an apparently negative disc exploration may be an indication for facetectomy.

UNDERMINING FORAMINOTOMY

Most surgeons operating in the area of the low lumbar vertebral canal have avoided exposure of the foraminal canal, since many feel that to excise the articular processes would seriously impair stability of the low back. As a consequence, the foraminal area has remained essentially *terra incognita*, at least at the operating table. Briggs has devised a limited approach to this region which has proved of value and he calls the procedure "undermining foraminotomy" (Fig. 14). His method affords easier access to the foramen than before and it becomes possible to palpate along the disc into the foramen with a bent probe *.

This procedure is also a means by which a disc protrusion in the lateral recess may be uncovered. The undermining foraminotomy admittedly is not a perfect solution to our diagnostic difficulties, but until a better one can be found, it does offer a practical compromise, avoiding on one hand inadequate exposure and on the other, the causing of low-back instability.

* Briggs has found probe palpation of the disc more reliable than calibration of the foraminal canal. It is possible for a nerve to be compressed above by a disc herniation "still leaving plenty of room in the canal as a whole".

NEGATIVE EXPLORATION AND EXTENDED EXPOSURE

A negative disc exploration represents a serious operative failure. If severe symptoms persist and further surgery becomes necessary, the second operation will be more difficult, more dangerous, and results are less likely to be successful. It is important, therefore, that at the initial operation the surgeon should feel confident of the existence of true nerve-root compression so that he will pursue the exploration as far as necessary.

CASE 5. J. M. G., a bartender, forty-five years old, with a ten-year history of recurrent backache, had persistent sciatica on the right for four months before examination. For five weeks the pain had been so excruciating that the patient had been bedridden. At examination he was in acute distress. The spine showed a right lumbar and left thoracic scoliosis, with a marked list to the left side. The lumbosacral spine was kyphotic. All motions of the lumbosacral spine were extremely restricted. Straight-leg raising on the right side was possible only to 20 degrees from the table. The right tibialis anterior and the long extensor of the right big toe were weak. Hypo-aesthesia was present over the posterolateral aspect of the right leg.

At operation on August 20, 1954, the fifth lumbar interspace on the right was entered with normal findings. The space above the fifth lumbar vertebra was cleared and appeared negative except for injection of the lower portion of the exposed right fifth lumbar nerve. A hemilaminectomy of the fifth lumbar vertebra on the right side was carried out, exposing a large disc protrusion extending toward the foramen which had been covered by the upper portion of the fifth lumbar lamina. This was incised and a large nuclear sequestrum was extruded.

The patient's relief from sciatica was immediate. Postoperatively, sensation and motor power in the right leg showed rapid improvement. At the last examination, on August 8, 1956, the patient stated that he had returned to his job about one month after the operation and had been working regularly since then without recurrence of backache or of sciatica. The spine showed no deformity and its flexibility was free. The lower extremities showed no impairment of motor power or of sensation. The knee jerks and ankle jerks were normal.

If we had not been convinced before operating that there must be severe nerve-root compression, it is doubtful that a hemilaminectomy would have been performed.

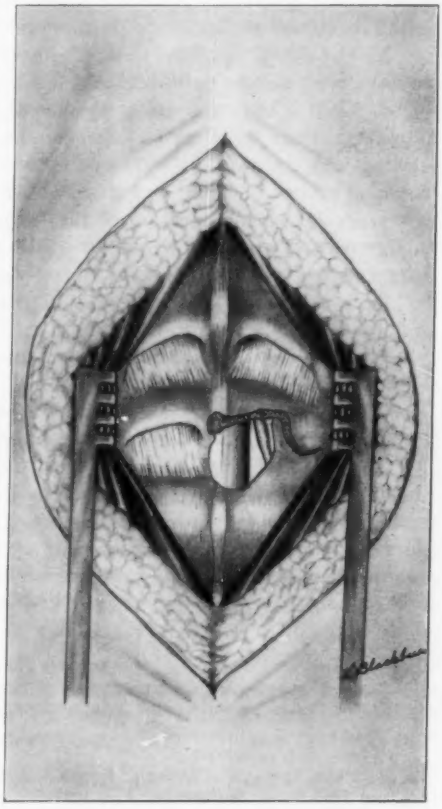

FIG. 14

Fig. 14: The Briggs undermining foraminotomy, stage 1. Some of the lamina and inferior articular process of the fifth lumbar vertebra has been removed, exposing a portion of the superior articular process of the sacrum. The procedure is concluded by excising the exposed portion of the superior articular process of the sacrum with an osteotome directed at an angle of 45 degrees laterally and anteriorly.

CONCLUSIONS

Before an exploration of the lowest two lumbar interspaces is abandoned as noncontributory, serious consideration should be given to an extended exposure by hemilaminectomy, facetectomy, or undermining foraminotomy. An ample exposure of the spinal canal is a necessary preliminary, and it has several advantages in itself:

1. The spinal nerve can be clearly seen before retraction, and if it lies in a contracted

space or if it is severely compressed or held taut by a large herniation, the means by which it may be released and retracted without undue damage will become apparent.

2. The extradural veins can be seen and it may be possible to retract the nerve and the dura medially without rupturing these vessels. One of the common causes of unsatisfactory results in disc surgery is the bleeding which inevitably follows tearing of the extradural veins. When this bleeding is severe, adequate exploration becomes almost impossible. Exploratory attempts under this handicap have led to damage of the exposed spinal nerve, laceration of the dura, and even to damage to the intrathecal roots.

3. The disc is disclosed to direct inspection and even to palpation. In some instances we have been able to palpate a mid-line protrusion through the dura.

4. Even if the exposure of the spinal canal does not show direct evidence of a disc herniation, then the clear visibility of the spinal nerve, the disc, and the lateral recess opening may indicate, by evidence found in the spinal canal, the direction in which an extended exposure should be carried out. Such evidence might be:

1. Pathological condition of the nerve root such as injection, oedema, scarring, or enlargement of the nerve root; or evidence of nerve-root adherence indicated by poor retractability or tension of the root; or angulation of the nerve root on retraction.

2. A contracted lateral recess, that is, the upward projecting articular process approximating the anterior structures.

3. Evidence of herniation into the foraminal canal or inadequacy of the canal, determined by probing or by calibration.

4. A positive tap test. (Mention of the tap test logically belongs here even though its evidence is usually noted before the spinal canal is entered.)

In Case 1, the clue to the herniation of the fifth lumbar disc in the lateral recess was the angulation of the first sacral nerve on retraction. In Case 5, the clue to the dissecting herniation of the fourth lumbar disc was the discovery of the injection of the fifth lumbar nerve; the dissecting herniation was then disclosed by hemilaminectomy. In Case 2, compression of the fifth lumbar nerve in the contracted lateral recess was suspected when it was seen that the articular process of the sacrum was practically in contact with the body of the fifth lumbar vertebra, and that the first sacral nerve was placed too far medially to be affected.

NOTE: The author wishes to thank Mr. Neil Creedon of Glens Falls for the photography and for his help in the cutting and preparation of the specimens used to illustrate this article.

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DISCUSSION

Gunshot Fractures of the Extremities

(*Continued from page 520*)

Dr. Edwin F. Cave, Boston, Massachusetts: In discussing this paper, which deals with fractures sustained by military personnel, we must remember that fractures occurring in military service differ profoundly from those which are encountered in civilian life. The typical war wound is due to gunshot or shrapnel and usually results in marked comminution of bone and extensive soft-tissue damage. Not infrequently adequate treatment is delayed, for in time of war the armed forces cannot be supplied with a sufficient number of adequately trained surgeons, skilled in meticulous and difficult bone and joint surgery.

In civilian life, on the other hand, while open fractures are common, the bone is generally not so shattered and even though soft-tissue damage may be great, it is usually possible to institute adequate treatment at an early date.

Open fractures of the femur in civilian life are relatively rare. In military service they are common. Open fractures of the tibia are common in both civilian life and military service. We do not hesitate to apply internal fixation to the *fresh* open tibial fracture seen in our emergency wards if this treatment is required in order to provide stability and if the wound can be closed either by suturing or by skin-grafting. The work of Lottes of St. Louis indicates that the use of the medullary nail in open tibial fractures is a reasonable procedure if it is employed by an experienced surgeon. In our own small series of cases this finding has been confirmed. In some cases the nail can be introduced from above without wide exposure of the fracture site. In most cases, however, the curving contour of the femoral shaft requires that the nail be introduced in a retrograde manner, which requires more extensive exposure of the fracture.

Without question medullary fixation of fractures of the long bones is the greatest advance in fracture management that has been made during the past fifteen or twenty years. It is a form of treatment which is here to stay, and in atomic war, when fractures of the extremities may be associated with great skin destruction, it may be the only means by which the bone can be stabilized.

In closed femoral fractures this treatment meets all the requirements for providing stability and allowing early joint motion and return of muscle function. In fresh, open fractures, when the injury is less than six hours old and when soiling is not great, it may be applied as a primary procedure. Properly applied internal fixation of a fracture gives stability and is, therefore, a deterrent to infection. In older wounds or in battle fractures of the femur, adequate débridement should be followed by secondary wound closure. When the tissue reaction has subsided, the nail may then be introduced. However, in these cases so much depends upon the amount of comminution or actual bone loss and on the extent of the soft-tissue damage that each fracture is a separate problem which must be treated individually.

Primary Malignant Tumors of Bone

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From 1922 through 1953, thirty-three Caucasian patients with primary malignant tumors of bone, exclusive of multiple myeloma, were seen and treated at the Scott and White Clinic. Approximately 300,000 patients had registered at the Clinic during this period, making the incidence of primary malignant lesions of bone one per 10,000 patients. In this series, pertinent case histories and pathological materials were reviewed, and Lichtenstein's [8] classification of tumors of bone was used as the basis for terminology and presentation of statistics.

TABLE I
OSTEOGENIC SARCOMA

Case	Age	Sex	Location	History	Treatment and Course	Result	Length of Survival *
1	42	M	Upper (?) humerus	Pain in right loin and testicle, 24 months; pain in shoulder, 2 months.	Biopsy; pelvic mass interpreted as metastasis. No biopsy of primary mass. Cordotomy and palliative x-ray therapy.	Dead	12 months
2	10	M	Lower femur	Pain in thigh, 1 month.	Biopsy; high-thigh amputation.	Dead	6 months
3	35	M	Distal radius	Mass in wrist. X-ray therapy given after roentgenographic diagnosis of giant-cell tumor.	Biopsy; amputation of forearm with axillary-node dissection (containing metastatic tumor).	Dead	9 months
4	44	M	Lower humerus	Pathological fracture; patient had generalized Paget's disease.	Biopsy; disarticulation of shoulder.	Dead	8 months
5	19	F	Lower femur	Pain in knee, 5 months. Aspiration of bloody fluid from knee. Pathological fracture just before admission. Twenty-pound weight loss.	Biopsy; hip disarticulation.	Dead	13 months
6	58	F	Upper femur	Pain and swelling in hip, 18 months. Unable to walk, 12 months.	Biopsy; hip disarticulation.	Alive, well	89 months
7	26	M	Upper femur, (?) pelvis	Pain in hip, 5 months.	Biopsy; local excision and x-ray therapy.	Dead	5 months

TABLE I *(continued)*

Case	Age	Sex	Location	History	Treatment and Course	Result	Length of Survival *
8	18	F	Upper humerus	Pain in shoulder, 24 months.	Biopsy; interpreted as malignant giant-cell tumor, curetted, packed, x-ray therapy. Ten years later node removed from supraclavicular region—osteogenic sarcoma.	Dead	11 years, 3 months
9	16	F	Upper tibia	Pain in knee, 3 months.	Biopsy; mid-thigh amputation.	Dead	26 months
10	51	M	Upper femur	Aching in hip, 6 years. Pathological fracture 3 months prior to admission.	Biopsy; cordotomy. (Metastases present in pelvis and vertebrae.)	Dead	6 months
11	59	M	Third lumbar vertebra	Pain in back and hips, 9 months.	Biopsy; palliative x-ray therapy.	Dead	24 months
12	18	M	Upper tibia	Pain in knee, 1 month.	Biopsy; mid-thigh amputation. (Metastasis present in chest 10 months after operation.)	Dead	14 months
13	15	F	Lower femur	Pain in knee, 4 months. Mass, 2 months.	Biopsy; hip disarticulation.	Alive, well	22 months

* After biopsy.

TABLE II
SURVIVAL RATES FOR OSTEOGENIC SARCOMA

Author	No. of Patients	Five-Year Survival Rate (*Per Cent*)
Lichtenstein	25	8.0
Coley	265	21.9
Geschickter and Copeland	121	15.7 (osteolytic)
	147	21.8 (sclerosing)
This study	13	15.4

During the period covered by our survey, fifty-one patients with multiple myeloma were observed—some being seen initially on the Orthopaedic Service. This condition should be considered by anyone evaluating bone lesions, particularly when the neoplasm is found in an older patient. These cases were reported previously [7].

An initial diagnosis of malignant giant-cell tumor has been made twice at this Clinic. Upon re-evaluation, one case was discarded from the group of malignant tumors and the other was reclassified as osteogenic sarcoma. Reticulum-cell sarcoma, described and established as a clinical entity in 1939 by Parker and Jackson, has not been observed.

OSTEOGENIC SARCOMA

Exclusive of multiple myeloma, osteogenic sarcoma is the most frequently encoun-

TABLE III
EWING'S SARCOMA

Case	Age	Sex	Location	History	Treatment and Course	Result	Length of Survival *
1	9	M	(?) Humerus, (?) ilium	Pain in right arm, 12 months. Pain in left hip, 6 weeks. Mass, left hip. Original diagnosis—osteomyelitis.	Biopsy; x-ray therapy.	Dead	1 month
2	22	M	Lower femur	Pain and swelling, 5 months.	Biopsy; x-ray therapy, radium therapy.	Dead	26 months
3	10	M	Upper femur	Pain and swelling, 6 months. Treated as osteomyelitis.	Biopsy; hip disarticulation. Coley's toxin.	Dead	11 months
4	24	M	Lower femur	Cervical lymphadenopathy. Hilar mass shown by chest roentgenogram. Later, pain in thigh.	Biopsy; x-ray therapy.	Dead	57 months
5	17	M	Upper femur	Pain in right hip, 4 years. Febrile, 9 months. Surgical drainage done for osteomyelitis 3 years prior to time seen.	Biopsy; x-ray therapy.	Dead	13 months
6	15	M	Lower fibula	Swelling and tenderness for 1 month; treated as osteomyelitis.	Biopsy; further treatment refused.	Dead	14 months
7	20	F	Distal radius	Pain in wrist, 1 month.	Biopsy; local excision, x-ray therapy.	Dead	12 months
8	13	F	(?) Pubis, (?) femur	Pain in thigh. Mass in pubis, 1 month.	Biopsy; x-ray therapy.	Dead	20 months

* After biopsy.

tered primary malignant tumor of bone. Opinion has varied as to the pathological differential diagnosis of this neoplasm, but, generally, it is agreed that a diagnosis of osteogenic sarcoma has been made too frequently. A tendency to lump cases of chondrosarcoma and central fibrosarcoma together with genuine instances of osteogenic sarcoma has been stressed by McDonald and Budd. When they reviewed and analyzed the pertinent material from the Registry of Bone Sarcoma of the American College of Surgeons, they concluded that ninety-three of the 118 tumors in patients who had survived for five years (79 per cent of the tumors initially diagnosed as osteogenic sarcoma) should have been classified as chondrosarcoma or fibrosarcoma. Failure to make a sharp pathological distinction between these tumors also has led to the indiscriminate use of mixed terms such as *osteochondrosarcoma*. The histological picture is variable, but Lichtenstein stated that the essential criteria for diagnosis of osteogenic sarcoma are: (1) the presence of frankly sarcomatous stroma, and (2) the direct formation of tumorous osteoid and bone by this malignant connective tissue.

TABLE IV
SURVIVAL RATES FOR EWING'S SARCOMA

Author	No. of Patients	Five-Year Survival Rate (*Per Cent*)
McCormack, Dockerty, and Ghormley	80	12.1
Lichtenstein and Jaffe	17	0
Coley, Higinbothan, and Bowden	73	4.1
This study	8	0

In our series of thirteen patients with osteogenic sarcoma, only two patients are alive (Table I). One has lived for eighty-nine months (seven years and five months) and the other for twenty-two months following the initial treatment. Nine (69 per cent) of the thirteen patients died within twenty-four months, and another patient died within thirty months, raising the mortality rate to 77 per cent during a period of two and one-half years. Only two patients have survived for more than five years, and one of these expired, apparently from metastases, after 135 months (eleven years and three months). These findings certainly substantiate the generally recognized poor prognosis for osteogenic sarcoma (Table II).

TABLE V
CHONDROSARCOMA

Case	Age	Sex	Location	History	Treatment and Course	Result	Length of Survival *
1	46	M	Lower femur	Slowly growing painful mass in posterior portion of knee, 6 years.	Biopsy; thigh amputation. Chest roentgenogram 9 months later showed metastasis.	Dead	12 months
2	69	M	Lower femur	Pain in low back and knee, 10 months.	Treated as disc for 4 months. Biopsy; hip disarticulation.	Alive	16 years, 9 months
3	32	M	Ischium	Pain in ankle, 24 months. Pain in lower limb, 6 months.	Biopsy; hemipelvectomy recommended. Surgery refused, x-ray therapy given 1 year later, pain relieved.	Alive	8 years, 11 months
4	67	M	Vertebra	Pain in back, 24 months.	Biopsy; partial removal of posterior mediastinal tumor. Pain relieved.	Dead	24 months
5	49	F	Mandible	Mass on mandible, 9 months.	Biopsy; resection.	Alive (terminal state)	60 months
6	27	F	Acetabulum	Pain in hip, 20 months.	Biopsy; hemipelvectomy, asymptomatic for 16 months after operation.	Dead	20 months
7	68	M	Upper femur	Pain in upper thigh, 7 months.	Biopsy; hemipelvectomy.	Alive	26 months

* After biopsy.

TABLE VI
SURVIVAL RATES FOR CHONDROSARCOMA

Author	No. of Patients	Five-Year Survival Rate (*Per Cent*)
O'Neal and Ackerman	28	21.4
This study	7	42.9

TABLE VII
FIBROSARCOMA

Case	Age	Sex	Location	History	Treatment and Course	Result	Length of Survival *
1	31	F	Upper femur	Pain and swelling in hip, 5 months.	Biopsy; local excision, twice re-excised. X-ray therapy 1 year after biopsy.	Dead	35 months
2	42	F	Lower femur	Generalized arthralgia, 8 months. Febrile, 6 weeks.	Biopsy; disarticulation of hip.	Dead	9 months
3	18	F	Lower femur	Pain in knee, 3 months.	Biopsy; mid-thigh amputation.	Dead	8 months
4	39	F	Pubis	Pain in hip and groin, 20 years. X-ray therapy for bone cyst done 11 years prior to time seen.	Biopsy; hemipelvectomy recommended and refused. No further treatment.	Alive (terminal state)	46 months
5	25	F	Lower femur	Aching with weakness in thigh, 6 months.	Biopsy; giant-cell tumor; curetted and packed; continued to expand. Biopsy 2 months later, malignant. Thigh amputation 4 months after original biopsy.	Alive, well	48 months

* After biopsy.

EWING'S SARCOMA

In 1921, Ewing described a tumor which he designated as "diffuse endothelioma of bone". Since that time, there has been much speculation and theorizing concerning (1) the delineation of this neoplasm, (2) the determination of its clinical and cytological features, and (3) the accurate diagnostic differentiation of this tumor from many other pathological lesions occurring in bone.

Ewing's sarcoma is well recognized in America, but Willis, of England, has stated that most lesions diagnosed as Ewing's sarcoma are metastatic lesions (usually neuroblastoma in children) or reticulum-cell sarcoma. To add to the confusion, Ewing included "angio-endothelioma" in his Registry classification of 1939, and usage has established this tumor as Ewing's sarcoma. Lichtenstein and Jaffe have designated Ewing's sarcoma as a separate category of malignant neoplasms which arise from mesenchymal connective tissue. Because multiple lesions are encountered frequently at the first examination, some investigators have postulated that Ewing's sarcoma has a multicentric origin and that it

TABLE VIII
SURVIVAL RATES FOR FIBROSARCOMA

Author	No. of Patients	Five-Year Survival Rate (*Per Cent*)
Batts	25	40.0
This study	5	33.0 (One of three patients adequately treated — alive, four years.)

should be placed in the category of systemic disease; this classification is not generally accepted, however. The clinical picture of Ewing's sarcoma is similar to and may be virtually identical with that of osteomyelitis (in our series, about half of the lesions were initially diagnosed and treated as osteomyelitis).

Our results in patients with Ewing's sarcoma are comparable to those reported in the literature (Tables III and IV). All of our patients were under twenty-five years of age, and none survived for five years. If many patients with this lesion are to be cured, treatment other than surgery and radiation will have to be found.

CHONDROSARCOMA

The incidence of chondrosarcoma of bone is somewhat lower than that of osteogenic sarcoma. This classification includes all malignant lesions arising from cartilaginous tissue. Chondrosarcoma ordinarily occurs in an older group of patients than does either osteogenic sarcoma or Ewing's sarcoma, and it has a much better prognosis. In spite of the fact that this entity has been well described and that its clinical features have been well established for many years, there is a reluctance to make the diagnosis. This hesitancy probably is due to the histological characteristics of this tumor which resemble those of other more malignant tumors of bone. These characteristics include the formation of calcareous deposits, the infiltration of existing trabecula, and the presence of regeneration or proliferation of normal bone as a part of the healing reaction which follows bone destruction by tumor invasion. Probably the presence of osteoid and calcific deposits has caused roentgenologists, orthopaedists, and pathologists to designate many of these tumors as osteogenic sarcoma. It is of value to make the distinction, however, because chondrosarcoma has a much better prognosis. Perhaps failure to delineate chondrosarcoma as a separate category from osteogenic sarcoma accounts for the wide variation in survival rates sometimes reported for the latter.

The better prognosis for chondrosarcoma is exemplified even in our small series in which three of seven patients survived for five years after the diagnosis was made (Tables V and VI). It is interesting to note that three of the seven patients were over sixty years of age and that five of the seven were over forty-five years of age—demonstrating that primary malignant tumors of bone do occur in older people as well as in young people.

FIBROSARCOMA

Fibrosarcoma of bone is defined as a primary malignant fibroblastic tumor exhibiting no tendency to form osteoid or bone either primarily or following metastasis. It may arise within the canal or periosteum. Like fibrosarcoma of other tissues, it is usually a slowly growing tumor with a tendency to recur after local excision. There may be an increased degree of malignant growth with time and the tumor is late to metastasize.

Only one of our five patients with fibrosarcoma of bone is alive and apparently free of disease (Tables VII and VIII). Only three of the patients had adequate surgical treatment,

however. Two of these three patients died less than a year following surgery, but the other patient has survived for four years and is apparently free of disease. This survival rate of one out of three is comparable to that found in most series of fibrosarcoma of bone.

NOTE: The statements and conclusions published by the authors are the results of their own study and do not necessarily reflect the opinion or policy of the Medical Service of the United States Air Force.

We wish to express our thanks to Dr. A. C. Broders, Sr., Dr. Charles Phillips, and Dr. J.C. Stinson of the Department of Surgical Pathology and Pathologic Anatomy.

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Radioactive Calcium Tracer Studies in Bone Grafts * †

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INTRODUCTION

During the last half century, the fate of bone grafts has been studied by many techniques; yet no general agreement exists at present concerning the sequence of events which follows the insertion of a bone graft. The availability of radioactive isotopes now makes possible tracer experiments which can show the distribution of some elements of the grafted tissues. The present study was undertaken in order to determine what information radioactive calcium (Ca^{45}) tracer techniques could add to our knowledge of the behavior of bone grafts. In particular, we have tried to determine what happens to calcium in and around a graft area. Does grafted calcium diffuse into adjacent bone or contribute to nearby callus formation, or is the grafted calcium removed by circulating blood as the graft area undergoes repair? Does the calcium supply to the graft area come from adjacent bone, or does it come from circulating blood?

In order to answer the first question we implanted homogenous-bone grafts containing Ca^{45} into dogs; in order to answer the second question we implanted non-radioactive homogenous-bone grafts into dogs which had been injected with Ca^{45}. Samples of blood were taken at intervals up to the time of sacrifice and were analyzed for specific activity. When the dogs had been sacrificed, sections from the graft, the callus, and the nearby bone were analyzed for stable calcium (Ca^{40}) and for radioactive calcium (Ca^{45}). Adjoining sections were examined histologically. Adjacent sections were autoradiographed, and the films were analyzed quantitatively for localized values of specific activity by means of a microdensitometer.

All of the quantitative data are given in terms of specific activity, that is, in microcuries of Ca^{45} per gram of Ca^{40}. Ca^{45} activities obtained densitometrically have been corrected for decay from the time of injection, a half-period of 163 days being used. Ca^{45} activities obtained by counting with Geiger-Müller counter have been corrected by means of Ca^{45} standards. Since the amount of injected Ca^{45} differed somewhat for different dogs, all the data were normalized to an injection of 0.1 millicurie per kilogram of body weight. The use of *specific activity* instead of the *total activity* of Ca^{45} made it possible to compare the activity values for blood with those for bone, which helped to indicate the source of deposited calcium and the time of calcification. The normalization made it possible to compare the specific activity results for different dogs.

MATERIALS AND METHODS

The animals used were adult, healthy, mongrel dogs, maintained in cages under standard laboratory conditions with additional precautions taken in order to minimize radioactive contamination. The dogs were fed a mixture of fresh frozen horse meat, bran, and water as one meal in the morning. The average daily intake of calcium was about 1.7 grams a day. Water was given *ad libitum*.

The Ca^{45} solutions for injection were prepared by diluting the Ca^{45} supplied by the Atomic Energy Commission (specific activity ranging from 0.6 to 4.2 millicuries per milligram of calcium) with distilled water

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and by adjusting the pH to 4 to 5 with dilute hydrochloric acid and sodium hydroxide. The standardization * of the Ca^{45} (maximum energy = 0.254 million electron volts; half-life = 163 days ± 1 day **) was carried out with a 4 π beta proportional counter. The standard deviation in the uncertainty of the absolute activity was ± 5 per cent.

Injections of Ca^{45} were performed by clean venipuncture; and leakage or loss of activity was minimized by multiple washings-through of blood, by delayed withdrawal of the needle, and by prolonged pressure on the puncture site after withdrawal. The adequacy in administering the dose was determined by measuring the residual Ca^{45} in the needle and syringe. The residual activity was found to average about 3 per cent and no corrections were applied for this small loss. A new syringe and needle were used for each injection and for each venipuncture for sampling. The dose levels of Ca^{45} for different dogs varied from 0.06 to 0.24 millicurie per kilogram of body weight.

The grafting procedures are summarized in Table I. Four dogs were used as donors, three of them having received Ca^{45} and the fourth having received no Ca^{45}. Bones from each of these donors were removed, separated from soft tissues under sterile conditions, and kept refrigerated at −20 degrees centigrade until used. Seven dogs served as recipients and received inlay grafts, approximately three to eight centimeters long by 0.5 to one centimeter wide, into the diaphyses of the long bones. The cortical grafts, the measurements and weight of which had been recorded, were either fitted into slots in the cortex or inserted in the medullary cavity. Weighed cancellous grafts were packed as granules into troughs formed in the cortex. The grafts were held in place when necessary by periosteal sutures.

A complete postmortem examination was performed on each animal, and many specimens of bone from different portions of the skeleton were assayed. Each grafted area was excised in full, and the graft segment was divided into three parts. One of these was fixed in formalin for histological studies, another was analyzed for specific activity, and the third was prepared for autoradiography.

Multiple histological preparations of each graft site were made by use of celloidin embedding and hematoxylin and eosin staining techniques. The amount of persisting grafted bone was estimated as follows: when cortical implants had been used, a fragment could be found which, because of its position and devitalized appearance, represented that part of the graft persisting intact. The indistinct border of the area of callus could be recognized by the differing patterns of trabeculation. On each slide the areas of callus and implant were circumscribed in ink. An ocular grid was used to make an approximation of the proportions of new bone and residual implant present. Each square of the grid (100 micra by 100 micra) which contained bone in more than half of its area was recorded as containing callus or implant depending upon which type of bone predominated. A summation of the results on all squares in the demarcated area yielded an estimate of the relative amounts of implanted and new bone.

For determination of specific activity, the graft site was divided into three parts as accurately as could be done with a scalpel under a hand lens. These three parts were called respectively the implant, the callus, and the bed, the latter being that portion of recipient cortex opposite the graft. Each of these specimens was known to contain variable amounts of materials from adjoining areas as demonstrated by histological examination of their counterparts. They represented regions of sampling and were not thought of as pure samples of the designated material.

Ca^{40} *analyses* of serum samples were carried out in triplicate by use of a modification of the method of Salomon, Gabrio, and Smith. The proteins of serum aliquot-samples were removed by precipitation with trichloracetic acid. Ca^{40}, in the protein-free serum, was precipitated directly as the oxalate at pH 4.5. After standing overnight, the precipitate was centrifuged and washed several times with dilute, freshly prepared ammonium hydroxide. After the final centrifugation the precipitate was dissolved in perchloric acid ($HClO_4$), and the oxalate ion was titrated with cerium $^{++++}$, nitroferrin being used as indicator. The serum aliquots were chosen to contain 0.02 to 0.07 milligram Ca^{40}. Conductivity water was used for all solutions. Routine checks of the procedure were maintained by titrating the cerium $^{++++}$ with standard oxalate ion, by blank tests for the indicator, and by a standard calcium solution to monitor the procedure as a whole.

For Ca^{40} analyses, the bone samples were prepared by dissecting the soft tissues from the bone. The cleaned bone was oven dried and was dry ashed in porcelain crucibles in a muffle furnace at 550 degrees centigrade for forty-eight hours. The Ca^{40} analyses were carried out in duplicate on aliquots of the dissolved dry-ash residue by means of either the procedure just described or the standard potassium permanganate titration procedure [1], depending on the calcium content of the sample.

Ca^{45} *analyses* of serum were carried out with the same samples as those used for the Ca^{40} analysis; Ca^{45} analyses of bone were performed on aliquots of the original dry-ashed solutions. The samples were prepared for beta-ray counting by precipitating the calcium as the oxalate. Prior to precipitation, sufficient carrier calcium was added to make each sample contain four milligrams of calcium. After precipitation, the solution was poured through a two-section glass filter, and the calcium oxalate was collected on a disk of filter paper.

* This absolute standardization is necessary only for purposes of dosimetry with regard to radiation effects. The other aspects of this study merely require a self-consistent relative standard.

** This value is a recent measurement obtained in this laboratory (J. B. W.) and is in agreement with the value obtained by C. F. G. Delaney and J. H. J. Poole, Phys. Rev., **89:** 529, 1953.

TABLE I

SUMMARY OF EXPERIMENTAL SCHEDULE

Dog No.	Procedures	Millicuries of Ca^{45} Injected or Implanted per Kilogram of Body Weight	Type of Graft	Location	Sacrificed at	Remarks
101	Injection	0.242			11 days	
104	Injection	0.242			26 days	
119	Injection	0.059			14 days	
102	Radioactive graft	0.00056	Cortical (intermedullary)	9 ribs, femora	5 days	Thoracic infection, died
103	Radioactive graft	0.00071	Cortical (intermedullary)	Humeri, femora, tibiae	10 days	Humeral fracture, died
106	Radioactive graft	0.0026	Cortical	Femora, tibiae	90 days	
107	Radioactive graft	0.0030	Cancellous	Femora, tibia	94 days	
105	Injection followed by non-radioactive graft	0.127	Cortical	Femur, tibiae	102 days	11-day interval between injection and graft
108	Injection during non-radioactive graft	0.187	Cortical	Femora, tibiae	93 days	Simultaneous graft and injection
109	Non-radioactive graft followed by injection	0.165	Cortical	Femora, tibiae	89 days	14-day interval between graft and injection

The filter paper was glued on a copper planchet, and the Ca^{45} content was determined by counting on automatic apparatus equipped with thin end-window Geiger-Müller counters. The Ca^{45} preparation procedure was monitored by the routine preparation of Ca^{45} standards. The counters were monitored with electroplated radioactive cobalt (Co^{60}) standards [4] and with a continuous record of gamma-ray background. Duplicate samples were counted, each for three cycles, a total of 3×4096 counts being accumulated.

In the specific-activity analyses, the recoveries of Ca^{40} and Ca^{45} were 98 ± 2 per cent. Standard deviations in the measurement of individual samples of Ca^{40}, Ca^{45}, and Ca^{45}/Ca^{40} were determined on large numbers of replicate samples and found to be 1 to 2 per cent, 2 to 3 per cent, and 2 to 4 per cent, respectively.

For *autoradiography* the bone was dehydrated through alcohols and xylol, and was embedded in bioplastic. The embedded bone was sectioned with a thin circular saw and faced on a lathe according to the method of Marshall, White, and Cohen. Exposures of a week to several months were made on Eastman Autoradiographic No-Screen plates. The plates were developed under carefully controlled conditions, and each development batch was calibrated with a Ca^{45} plaster-of-Paris radiator. This radiator, consisting of several areas of graded activities as described by Dudley and Dobyns, contained quantities of Ca^{45} standardized within ± 5 per cent by 4π beta counting. The blackening of the autoradiographs was measured with a microdensitometer. The microdensitometer consisted of a standard densitometer (Macbeth-Ansco Colar Densitometer, Model 12), the photocell head of which was adapted to fit a standard photomicrographic camera. The aperture for the densitometer was located at the optical axis of the microscope in the plane normally occupied by the camera film. With a microscope magnification of 63 ×, this aperture corresponded to a circular aperture 80 microns in diameter on the autoradiograph located on the object plane of the microscope. All other apertures of the microscope were reduced as much as possible in order to minimize the amount of stray light entering the aperture of the densitometer.

The autoradiographic density data were reduced to terms of specific activity as follows. By use of different exposure times with the Ca^{45} radiator, the density of the film was measured as a function of relative exposure. From this observed relation, the densitometer data were corrected for slight non-linearity. The relation between corrected density (less film background) and specific activity can be expressed as follows:

1. $D = a r k F$

where

D = measured net density corrected for non-linearity;

a = specific activity of bone in microcuries per gram of calcium referred to the time of injection;

r = grams of calcium per gram of bone as embedded = 0.25;

(the value $r = 0.25$ was used for all the autoradiograph data; however, subsequent measurements gave 0.250 and 0.235 gram of calcium per gram of embedded bone);

k = film density produced per microcurie per day per gram of embedded bone;

f = exposure time in days corrected for the decay of Ca^{45} (half-life = 163 days).

A similar relation applies to the plaster-of-Paris radiator:

2. $D^* = a^* r^* k^* F^*$

where

D^* = measured net density of the radiator spot;

$a^* r^* = Ca^{45}$ activity per gram radiator (measured by a 4 π counting);

k^* = film density per microcurie per day per gram radiator;

F^* = exposure time used for the radiator.

Since the same beta-ray emitter (Ca^{45}) is used in both the bone sample and the radiator, k will equal k^* if the curve of absorption of beta rays in relation to superficial density (milligram per square centimeter) is the same for embedded bone as it is for plaster of Paris. The respective densities of bone and plaster of Paris are not important so long as the diameter of the active area is large compared with the range of beta rays. Since plaster of Paris has an atomic composition comparable to that of bone, the assumption that $k = k^*$ should be excellent, and we may solve for a, the specific activity in a small region of bone from the above expressions:

3. $$a = \frac{D F^* a^* r^*}{D^* F r}$$

This relation between the specific activity in bone and the density of the autoradiograph film applies properly to thick, uniformly distributed sources. The maximum range of Ca^{45} beta rays is about sixty milligrams per square centimeter (300 micra in cortical bone with observed density two grams per cubic centimeter). Since all bone sections that were autoradiographed were at least 300 micra thick, the thick-source requirement was fulfilled. The resolution of the method (thick source in contact with an autoradiographic plate) was measured by embedding a thread ten micra in diameter drawn from a viscous sugar solution containing dissolved radioactive calcium chloride, and by exposing a film to a cross section of the thread. The resulting exposure spot, measured with the eighty-micra densitometer aperture, showed a characteristic density profile with a width at half maximum density of about 120 micra. The specific activity derived from a microdensitometer reading therefore represents the effective average specific activity whose distribution is uniform in a cylinder with a diameter of about 120 micra. The autoradiographic values for effective specific activity reported in the tables have been calculated as if the activity were in the above distribution and therefore these values underestimate the actual specific activity in proportion to the non-uniformity of its distribution.

The error (standard deviation) in the densitometric specific activity, a, is a proper summation of the errors in the variables of Equation 3. The errors in the exposure factors F and F^* arise from the uncertainty in the half-period of Ca^{45}, applied to the time between injection and the conclusion of exposure. With an error of one day in the Ca^{45} half-period, the maximum errors in F and F^* are calculated to be 3 per cent and 1 per cent, respectively. The quantity $a^* r^*$ has an error of 5.5 per cent and is primarily due to the error in the standardization of Ca^{45} with the 4 π counter. The quantity r^* has been determined independently and is 0.240 ± 0.002 gram of calcium per gram of radiator, this determination falling between the two corresponding measured values for bone. The error in the quantity r is approximately 3 per cent. Therefore, the combined error or standard deviation in the quantity $F^* a^* r^*/Fr$ is approximately 7 per cent and is nearly constant for all the densitometric measurements.

Measurements with the eighty-micra circular aperture result in a standard deviation of approximately 5.5 per cent for density values between 0.6 and 2.5. This error is primarily due to the number of grains per unit area in the film. Since the error due to subtracting film background density is relatively small at these density values, the error in net density, D and D^*, is about 5.5 per cent, although theoretically it is expected to decrease slowly as the density increases to higher values. Thus, the error in the quantity a is 10 to 11 per cent for values of net density equal to or greater than about 0.4 when background density is about 0.2 to 0.25, and is the minimum error for any value of a. As the density decreases below about 0.6, the errors in D and D^* begin to increase rapidly due to two additional factors: the significant fluctuations arising from the number of beta rays per unit area interacting with the film, and the error due to the increasing relative importance of film background density in total density measurements. The error in the observed calibration curve for the response of the film to exposure is a third factor, small when compared with the other errors at total density values greater than about 0.3, but increasingly significant as the density values decrease below about 0.3. Therefore, as the net density values D and D^* decrease to 0.4, 0.2, and 0.1, the error in the quantity a increases to approximately 20 per cent, 45 per cent, and 70 per cent, respectively. At some of the lowest densities which have been measured, the error or standard deviation approaches 100 per cent.

No fading was detected over the two-month period of the long exposure.

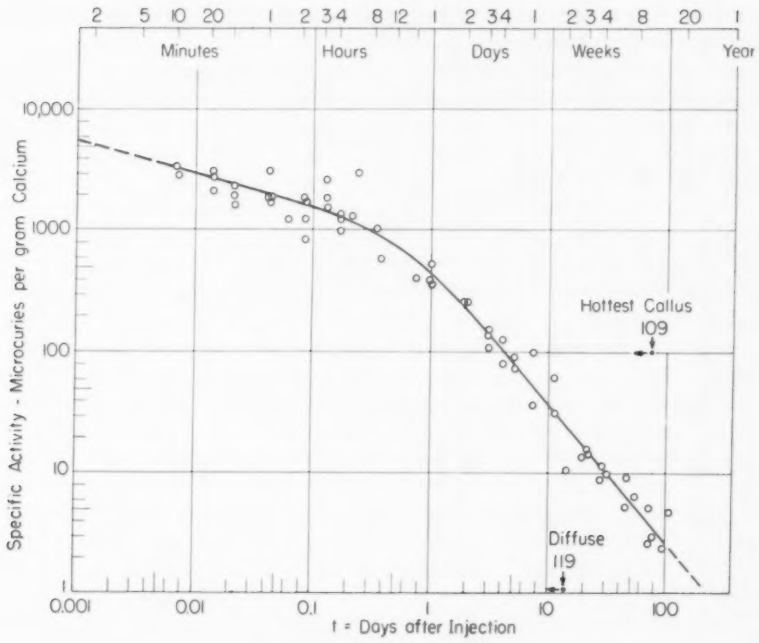


CHART I

Serum specific activity of dogs injected with Ca^{45}. A log-log plot is presented for convenience. The specific activity decreases monotonically over the entire observation period. The dotted sections at the two extremities of the curve are extrapolations. The dogs represented in the figure are not identified since there was no significant difference between the animals. All points are normalized to an injected dose of 0.1 millicurie per kilogram of body weight. The specific activity of the most active callus (dog 109, left tibia) and a characteristic diffuse value (dog 119, right femur) are included for comparison.

RESULTS

The specific activity of the blood in microcuries per gram of calcium is plotted as a function of time after injection in Chart I. Different dogs showed no significant variation from the curve, so measurements on all injected dogs were plotted together, after normalization to an injected dose of 0.1 millicurie per kilogram of body weight. The dashed curves represent extrapolations from the solid curve at its extremities.

A summary of the measurements of specific activity in bone is given in Table II under three headings: (a) donor dogs injected with Ca^{45}, (b) dogs receiving radioactive grafts, and (c) dogs receiving non-radioactive grafts and injections of Ca^{45}. The densitometer data for bone outside the graft areas are given in three columns: maximum hot spot, diffuse, and periosteal or endosteal maximum. The utility of this separation can be seen by reference to Figures 2 and 3. The distribution of activity in cross sections of the shafts of the long bones consists in a general diffuse component upon which are superimposed a few intense hot spots and often a ring of increased activity in or near the endosteum or periosteum. The diffuse activity, which contains the largest fraction of the total activity in the shaft, has a relatively constant specific activity of about one microcurie per gram of calcium for all the dogs when normalized to an injected dose of one millicurie per kilogram of body weight, whether they lived twelve days or 100 days after the injection. Because of the normalization of the data to one dose, this constancy means that the specific activity of the diffuse component is proportional to the injected dose. The contrast between the relatively constant values for the diffuse component (Table II) and the decreasing serum specific

activity (Chart I) is to be emphasized even though the error in the measurement of the diffuse component may be as much as a factor of two.

The hot spots correspond anatomically to individual Haversian systems. The obvious variation in specific activity of the hot spots (Table II) and in their numbers and anatomi-

TABLE II

II - A. S.A. of Specimens from Radioactive Dogs without Grafts

	Autoradiograph Data						Counter Data		
Dog	Maximum Hotspot	Diffuse	Periosteal Maximum	Maximum Implant	Average Implant	Maximum Callus	Bed	Implant	Callus
101	21	0.6	—				0.8		
104	18	1.0	3.4				2.1		
	12	1.0	2.3				2.0		
	21	1.4	3.3				4.0		
119	38	1.1	4.2				—		
Average Value	20	1.0	3				2		

II - B. S.A. of Specimens from Non-radioactive Dogs with Radioactive Grafts

103	<0.2	<0.2	<0.2	32	—	<0.2	<0.01	—	—
	<0.5	<0.5	<0.5	24	0.9	<0.5	<0.01	—	—
106	<0.5	<0.5	<0.5	23	1.6	<0.5	0.021	1.7	0.1
	—	—	—				0.013‡		
107	<0.5	<0.5	<0.5	10	2.3	<0.5	0.046	0.7	0.4
	—	—	—				0.020‡		

II - C. S.A. of Specimens from Radioactive Dogs with Non-Radioactive Grafts

105	25	1.0	—	—	—	9	1.5	0.7	0.7
108	5	0.6	81	7	5 *		1.9	8.5	8
	24	1.9	9.5	15	—	—	2.9	8.5	8
	14	0.9	11	17	8 *		1.7	9.1	6
109	21	1.0	39	36	9	110	41 *	57	55
	17	0.6	12	* —	—	—	5.5	56	86

(See page 567)

cal distribution (Figs. 1 and 2) required an arbitrary threshold of density for defining a hot spot. For the purposes of this experiment, the threshold was set at double that of the diffuse component, provided the characteristic density profile on cross diameters on the hot spot was present. This procedure avoided confusion of film artefacts with hot spots. The maximum hot spot in the cross sections of long bones was found to average twenty microcuries per gram of calcium as measured with the 120-micron resolution and normalized to an injected dose of 0.1 millicurie per kilogram of body weight. With higher resolution, the maximum hot-spot value would probably be higher.

The average specific activity, determined by beta-ray counting, of a segment of cortical bone in the graft bed, that is, the cortical segment opposite the area of graft insertion, is about twenty microcuries per gram of calcium. This value compares favorably with the autoradiographic data since the bed value should be somewhat higher than the diffuse value because it contains some hot spots and periosteal or endosteal activity.

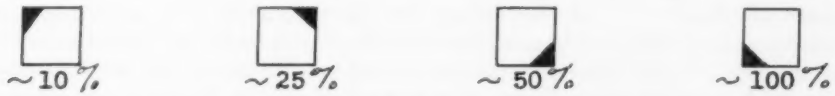
The specific activity data for bones obtained from dogs which received radioactive grafts are shown in Table II, *B*. The autoradiographic data for the graft areas are given in three columns: maximum implant (representing the most active regions in the implant area), average implant (representing the average of the entire implant area), and maximum callus (representing the most active region of callus). These regions were identified from their relative positions on the autoradiograph and the corresponding section. Because all the data for these dogs have been normalized to the injected dose of their donor dogs, the average values of specific activity shown in Table II, *A* represent the values expected to be found for the unabsorbed portions of the implants in Table II, *B:* "maximum implant" in Table II, *B* corresponds closely to "maximum hot spot" in Table II, *A;* "average implant" in Table II, *B* corresponds to "diffuse" in Table II, *A;* the counter value for "implant" in Table II, *B* corresponds closely to "bed" in Table II, *A*. Estimates of the total amount of activity, as distinguished from the specific activity, implanted into dogs 103, 106, and 107 are given in Table I.

The important result apparent in Table II, *B* of the autoradiographic data is that, within the limit of measurement, no activity was detectable outside the area of the implant. The upper limits for the specific activity near a hot graft are set by the background of the film, by the limited exposure times, and by the activity of the particular samples, which had decayed several half-periods before autoradiographs were made.

The counter data are more sensitive than the autoradiographic data and show de-

In Table II are shown the specific activities (microcuries per gram of calcium) of normal and grafted bone areas obtained by autoradiographic and counter measurements.

All values are normalized to an injected dose of 0.1 millicurie per kilogram of body weight. A dash indicates that data for the item were not obtained. A blank indicates that the column does not apply to the particular sample. A less-than sign (<) represents a practical limit of sensitivity in the measurement of the value and indicates that the value is less than that recorded or, alternatively, that the value cannot be larger than that recorded. The standard deviations for the autoradiographic values are given by the following error code:



The standard deviations for the counter values are all <10 percent and are not specified individually. Errors due to biological sampling are specifically noted. See section on autoradiographic method in text for the physical limitations on the meaning of autoradiographic S. A.

‡ These values are for tail vertebrae to represent samples distant from any grafted area in dogs 106 and 107.

* These values represent areas where no differentiation between callus and implant could be made grossly. Compare Figs. 5 and 6.

† This value is probably inaccurate due to inclusion of callus in sampling.

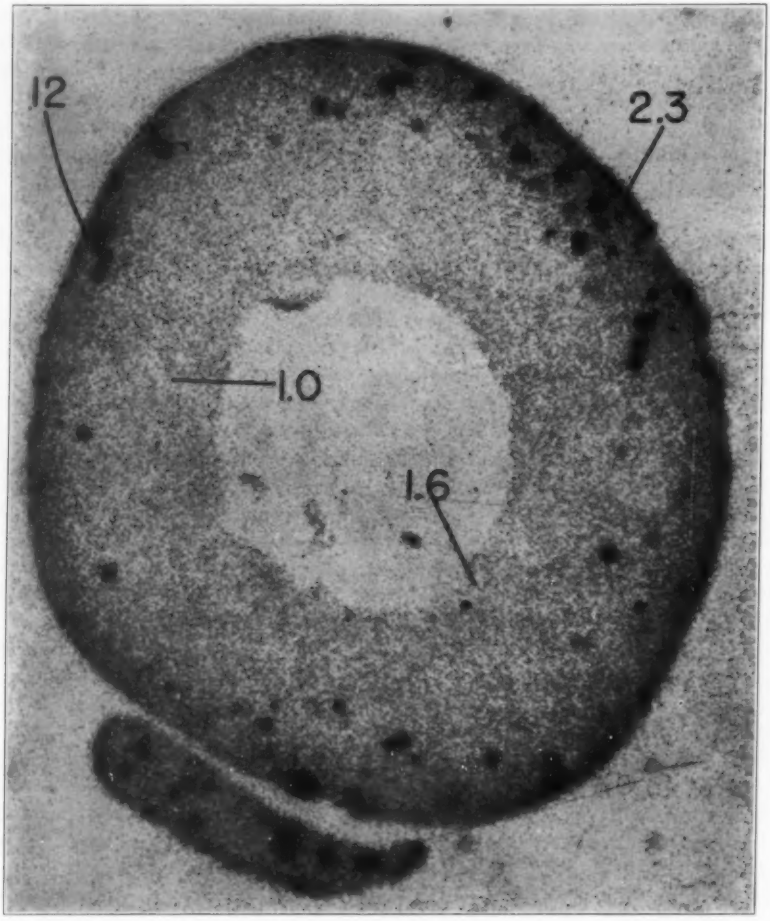


FIG. 1

Autoradiograph (× 15) of cross section of left tibia of dog 104, a donor injected with Ca^{45} twenty-six days before sacrifice. The hot spots are irregularly distributed and seem to predominate in the subperiosteal compacta especially under the external circumferential lamellae. The maximum hot-spot specific activity was twelve microcuries per gram of calcium for the large hot spot situated at about 10 o'clock. The periosteal maximum (at 2 o'clock) was 2.3 and the endosteal (5 o'clock) was 1.6. The diffuse value was 1.0 microcurie per gram of calcium and was constant within a factor of 2 throughout the section. All data are normalized to an injected dose of 0.1 millicurie per kilogram of body weight.

tectable specific activity in the bed of dogs 106 and 107, that is, in the cortical bone near the hot-graft area. From the data of Table II, *A* the maximum hot spot would be expected to have about ten times the specific activity of the bed. Therefore, one would not expect to observe hot spots in autoradiographs of recipient bone from dogs in which radioactive grafts were implanted unless the lower limit of detectability on the autoradiographs was 0.1 instead of 0.5 microcurie per gram of calcium. The specific activity of the bed in dogs 106 and 107 may be compared with the values for tail vertebrae in the same dogs. The specific activity of the blood at the time of sacrifice was 0.33 microcurie per gram of calcium for dog 106, and 0.26 microcurie per gram of calcium for dog 107. Blood measurements for other times were not made. It is evident that some of the activity from the hot grafts has been redeposited throughout the body by way of the circulating blood. Whether

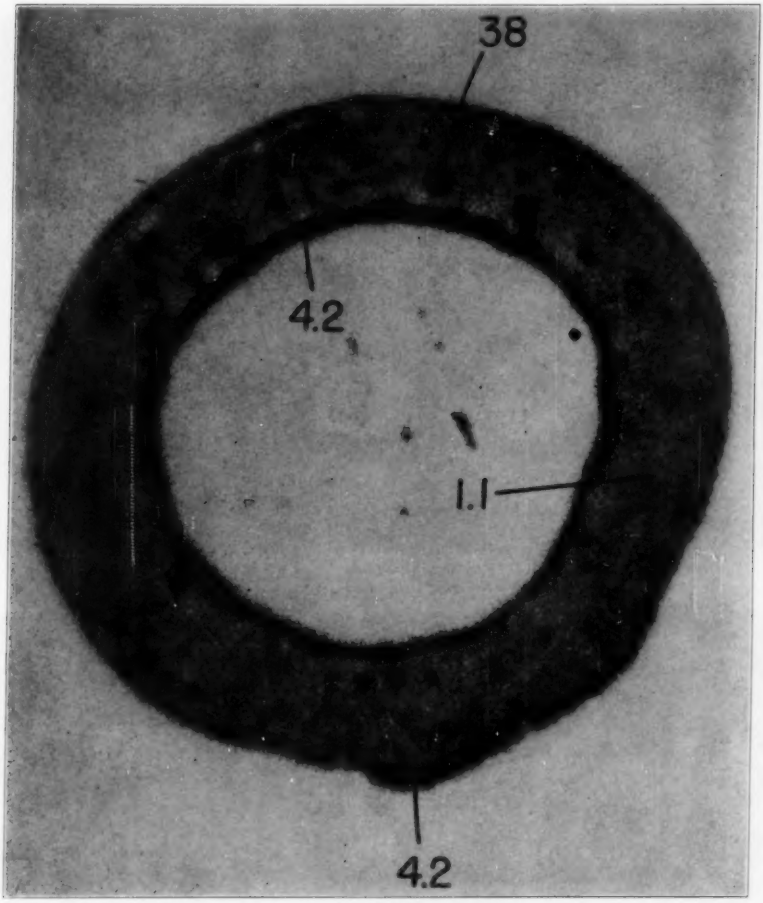


FIG. 2

Autoradiograph (× 15) of cross section of right femur of donor dog 119, injected with Ca^{45} fourteen days before sacrifice. The hot spots are more irregularly distributed than those of Fig. 1. The endosteal area shows a high activity over most of its circumference. The maximum hot-spot specific activity was thirty-eight microcuries per gram of calcium for the hot spot at 12 o'clock. The endosteal maximum measured at 9 to 12 o'clock and the periosteal maximum at 6 o'clock were 4.2. The diffuse activity was 1.1 microcuries per gram of calcium and was constant within a factor of 2. All data are normalized to an injected dose of 0.1 millicurie per kilogram of body weight.

the counter bed values for these two dogs indicate a significantly higher deposition of active calcium near the graft than in the body as a whole is doubtful. Additional and unpublished data from this laboratory have shown that in adult dogs the specific activity of adjacent small volumes in the diaphyses may vary by as much as a factor of three, that the average skeletal specific activity is slightly higher than the diaphyseal specific activity and that the tail vertebrae may have specific activity two to three times higher than the skeleton. From these data one may at least say that the specific activity near the hot grafts is comparable with that in the rest of the skeleton. Considering how small a quantity of bone immediately surrounds a graft, compared with the total skeleton, we may conclude that very little, if any, of the graft calcium is preferentially utilized near the graft.

The autoradiographs used to obtain the data for Table II are exemplified by Figures 3-A and 3-B which show a photograph and corresponding autoradiograph of a section of

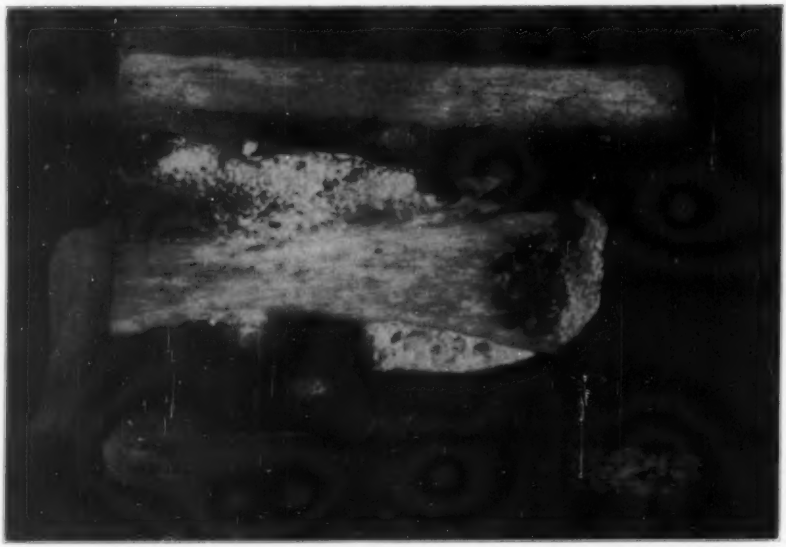


FIG. 3-A

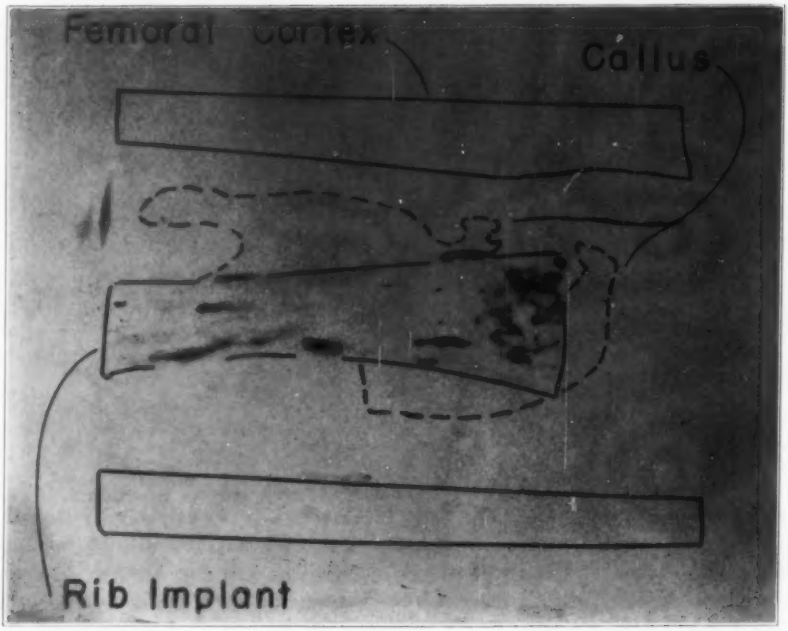


FIG. 3-B

Figs. 3-A and 3-B: Photograph and corresponding autoradiograph (× 5) of longitudinal section of radioactive graft of rib segment from dog 101 implanted into left femur of dog 103, ten days after grafting. The cancellous structure of the right-hand portion of the rib is well shown and this provides the lacework pattern of the activity in the autoradiograph. The rib cortex has a few active areas and in general is much less active than the cancellous portion. Callus in moderate amount is present particularly on the right end and both sides of the implant. India ink outlines of the implanted rib and femoral cortex (solid line) and of major portions of callus (dashed line) have been superimposed on the autoradiograph. Neither callus nor femoral cortex shows detectable activity.

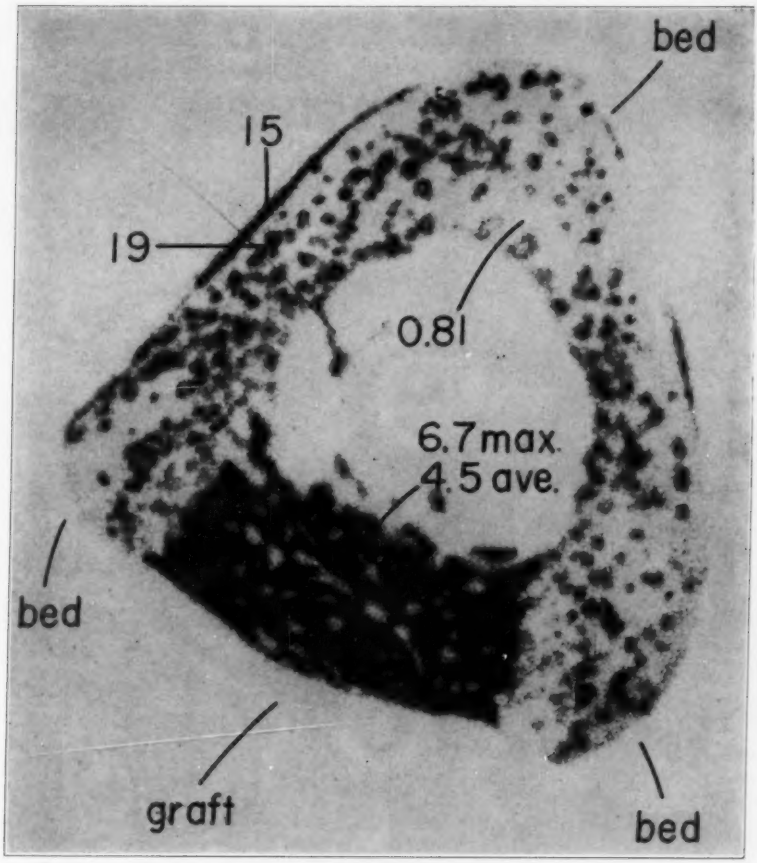


FIG. 4

Autoradiograph (× 15) of a cross section of a graft and its bed from dog 108, which was implanted and simultaneously injected with Ca^{45} ninety-three days before sacrifice. The maximum graft specific activity measured at the central portion of the graft near the endosteum was 6.7 microcuries per gram of calcium, while the average specific activity was 4.5. The periosteal portion at 10 o'clock measured 15. The maximum hot spot in the same region was 19. The diffuse activity was 0.81 microcurie per gram of calcium. The two bands of lesser density flanking the graft contain devitalized bone of the host, as demonstrated histologically. These devitalized areas, burned by the rotary saw, have taken up less activity than the diffuse component elsewhere in the section. All data are normalized to an injected dose of 0.1 millicurie per kilogram of body weight.

rib from dog 101 implanted in the medullary cavity of the left femur of dog 103. There is a sharp boundary between the activity of the implanted rib and its surrounding host bone. A considerable quantity of callus can be seen, some of it in intimate contact with the active implant. Yet none of the callus shows detectable activity. If more than one-tenth of the calcium in the callus had been obtained from the implant, the callus activity could have been detected on the autoradiograph. The counter callus values for dogs 106 and 107 are not zero, but they do not necessarily indicate a slight callus activity because, as mentioned in the section dealing with methods, it was difficult to obtain a counter sample of callus without contamination with implant material.

The specific activity data for the injected dogs which received non-radioactive grafts are shown in Table II, *C*. The values for maximum hot spot and for diffuse activity are not significantly lower than the values in Table II, *A* for the donor dogs, despite the fact that

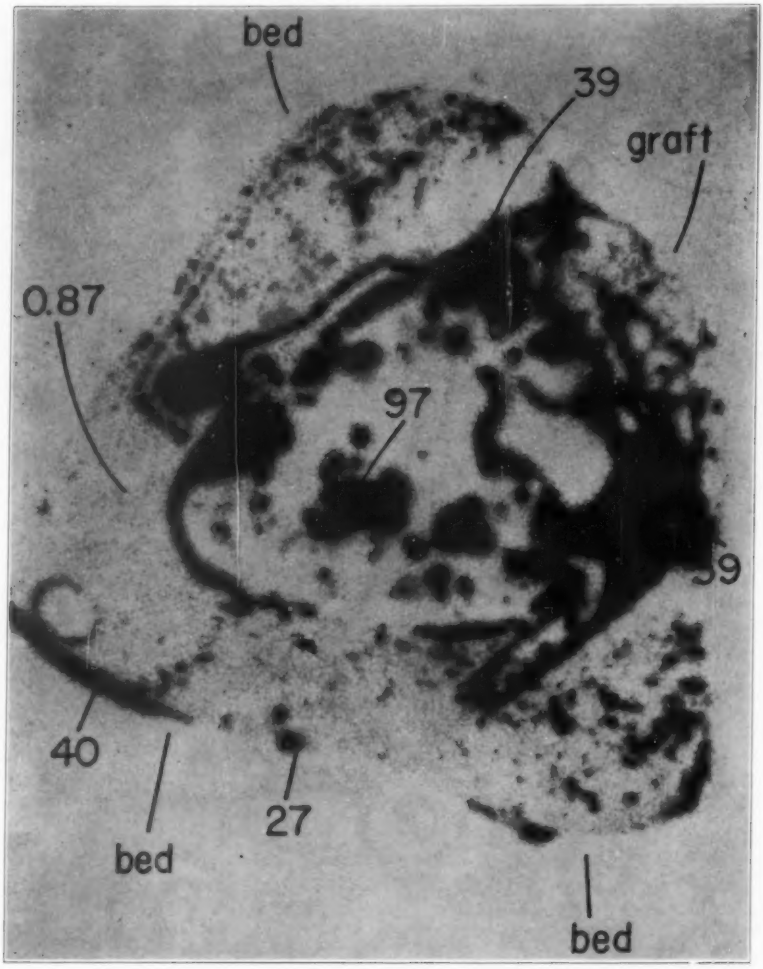


FIG. 5

Autoradiograph (× 15) of a cross section of a graft and its bed from dog 109, which was grafted, injected two weeks later with Ca^{45}, and then sacrificed eighty-nine days later. The maximum graft specific activity measured thirty-nine microcuries per gram of calcium, while that of the callus in the center of the medullary cavity measured ninety-seven. The average specific activity of the entire graft area was 9.1. The periosteal maximum (8 o'clock) was forty. The maximum hot spot (6 o'clock) measured twenty-seven. The diffuse value was 0.87 microcurie per gram of calcium. Two saw cuts have penetrated into the cortex opposite the graft and show, as in Figure 5, specific activity adjacent to the devitalized host bone lower than the diffuse. All data are normalized to an injected dose of 0.1 millicurie per kilogram of body weight.

most of the hot spot and diffuse values in Table II, *C* were measured only a few millimeters from a graft area.

Figure 4 shows a cross-section autoradiograph of the left tibia of dog 108, which was grafted and injected simultaneously. Hot spots and diffuse activity are seen throughout the cortical recipient area. The cancellous-graft area at the lower left shows a high concentration of activity within the graft. The implanted bone, however, originally contained no activity, and therefore, the activity found in the graft at the time of sacrifice is due to the process of reconstruction during the ninetey-three days which elapsed between grafting

and sacrifice. Histological examination showed that the activity may be attributed to callus in the interstices of the implant. By histological assay only about 8 per cent of the implant area represents residual graft. There are two zones of lesser specific activity at the side of the callus area which contain recipient bone devitalized by burning by the rotary saw.

Figure 5 is an autoradiograph of the left tibia of dog 109, which was injected two weeks after grafting. The implant area, at the upper right, contains much less activity than that in Figure 4. The histological assay showed that the implant area contains about 65 per cent residual implant. The two saw cuts containing callus reach into the cortex opposite the graft, and next to each is an inactive cortical zone devitalized by the saw. The callus shown in Figure 5 has the highest specific activity measured in this experiment: about 100 microcuries per gram of calcium, the counter and autoradiograph measurements agreeing fairly well. The activity of the callus, as shown in Figures 4 and 5, is characterized by the absence of hot spots and is distributed rather diffusely and in a continuous pattern as compared with the activity distribution of cortical bone in these and other cross sections.

The data of Table II, *C* show that the callus laid down either in or around the implant has a specific activity which depends strongly upon the time of injection relative to the time of grafting. Dog 105 was injected eleven days before grafting; dog 108 was injected on the day of grafting; and dog 109 was injected fourteen days after grafting. The specific activity of the callus of dog 109 is by far the highest, reaching 100 times the diffuse activity. It is evident that this activity did not come from the cortical bone near the graft area since that region shows approximately the same specific activity it would have if there were no graft nearby. There is a significant increase in the periosteal activity opposite the graft areas because of subperiosteal deposition of new bone. A comparison of Table II, *A* with *C* with respect to "maximum hot spot", "diffuse", and "bed" specific activity reveals the corresponding values to be very similar, and therefore, suggests that despite multiple grafting procedures on the dogs listed in Table II, *C*, no apparent perturbation of the distribution of injected Ca^{45} has occurred in these animals.

DISCUSSION

In discussing these data as they pertain to bone-grafting, three points must be emphasized:

1. A single element, calcium, is being traced in the grafting procedures. Since many other elements compose the bony substance of the host, of the graft, and of the callus, it should not be assumed that the other elements are similar to calcium in their mode of redistribution; each may follow a separate course.

2. Our results apply to homogenous grafts of refrigerated bone in dogs; other grafting methods may give entirely different data.

3. The tracing of an element may not portray the entire effect of the grafting procedure; whether these grafts stimulated, retarded, or had no influence on the healing process at the operative site is too speculative for discussion here.

The data do demonstrate that under the conditions of the experiments, the calcium of the grafts entered the blood and was distributed in a manner indistinguishable from that of calcium entering the blood from other sources. No evidence can be drawn from the data for local preferential transfer of calcium to the callus from grafts or from bone stores adjacent to the grafted area. On the contrary, all of the data may be used to support the hypothesis that the calcium in callus is entirely derived from the serum.

If callus is indeed derived entirely from the serum, then it should be possible to predict callus specific activity by calculation from the known blood curve (Chart I) and from knowledge of the time interval after grafting during which callus calcifies. Variations in the timing of callus formation occur, but let us assume for the moment that these variations are not large. The data from dog 109 can be used to indicate a reasonable arbitrary

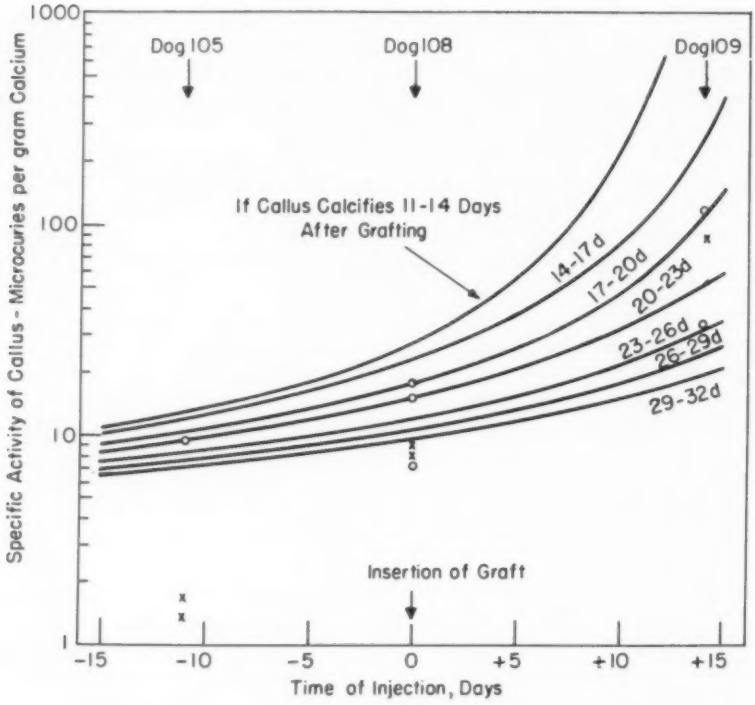


CHART II

Comparison between observed and predicted specific activity of callus as related to the injection-graft interval. Each group of points (circles for autoradiographic data and crosses for counter data) represents experimental callus specific activity obtained from each dog according to its injection-graft interval indicated on the abscissa. The solid lines are a family of curves of the calculated average specific activity of serum extending from fifteen days before to fifteen days after grafting, and occurring during the assumed callus-formation periods designated on the curves. These calculated values represent the predicted specific activity of callus, assuming that it calcifies entirely from serum calcium during the designated three-day intervals and that the rate of calcium deposition in the callus is uniform during these three days. The data for the curves are obtained from the serum specific activity curve of Chart 1, with the time scale of Chart 1 appropriately adjusted to the injection-graft interval. For example, assuming that most of the callus calcified in the three-day interval seventeen to twenty days after grafting, the calcium in the callus of dog 105 (injected eleven days prior to grafting) would have been derived from serum with an average specific activity of about ten microcuries per gram of calcium, which was the average level twenty-eight to thirty days after injection on Chart 1. All data are normalized to an injected dose of 0.1 millicurie per kilogram of body weight.

interval during which it may be assumed for purposes of the calculation that all calcium deposition occurs. In this dog, injected fourteen days after grafting, the high specific activity of callus indicates that most of the calcium in the callus was deposited in the third week after grafting. At less than two weeks, the blood contained no activity, and at more than three weeks after grafting the specific activity of the blood had dropped below the level at which the most active callus could possibly have been formed. If a three-day interval is chosen (for example, fourteen to seventeen days after grafting) as a reasonable period during which the greatest amount of calcium is deposited in callus, and if it is assumed that the rate of calcium deposition is uniform during these three days, the average specific activity of the blood during this period will be the predicted specific activity of callus for injection time fourteen days after grafting. A similar calculation made for all injection times extending from fifteen days before grafting to fifteen days after grafting has been made and is represented in one of the curves of Chart II. The other curves represent

similar calculations based on the assumptions that most of the calcium callus is deposited in the designated three-day periods after grafting. The observed maximum specific activity of callus in implants for dogs 105, 108, and 109, are also plotted on this figure according to the time of injection relative to grafting. It is interesting that the maximum specific activity of callus in or around the implant corresponds predominantly to the average specific activity of the blood for a three-day period between seventeen and twenty-six days after grafting, whether the time of injection was eleven days before, the same day as, or fourteen days after the grafting procedure.

The maximum observed callus values obtained from the autoradiographs should be the most reliable in this comparison because most of the possible errors of measurement, impurity of counter callus samples, resorption of callus during the life of the dog, and low autoradiographic resolution would tend to reduce the specific-activity values. If intervals longer than three days (for example, six or fourteen days) are chosen over which to calculate the average blood specific activity, the curves which fall close to the 17–20, 20–23, and 23–26 day curves are those for 16–22 days or 14–28 days. Comparison of blood and maximum callus specific activity does not yield a very sensitive method of timing callus calcification, but despite this lack of sensitivity, it provides a quantitative check that callus calcium does indeed come from the circulating blood. For if any reasonable period is chosen for callus calcification at about two to three weeks after grafting, then the average specific activity of the blood during that period falls very close to the maximum callus values for dogs 105, 108, and 109.

In studies of the deposition of radioactive isotopes in bone, the question often arises whether high local concentrations of radioactivity are fixed in the same region of bone from the time they are deposited until the time they are recorded on autoradiographs. The term "hot-spot migration" is often used to describe a possible relocation of radioactive deposits without dilution in the whole volume of circulating blood, that is, deposition at a specific activity greater than that of the blood at the time of deposition. In the results in Table II, *B*, no evidence of hot-spot migration from radioactive grafts has been observed. This result, however, may not apply to a normal situation since it refers essentially to the implantation of a foreign body. The observations of Table II, *C* may represent a more nearly normal situation from the point of view of migration. The formation of active callus presents a demand for calcium on the body to which nearby areas of recipient bone have not responded preferentially, since the hot spot and diffuse specific activity are approximately as high as those in injected dogs with no grafts.

In a fracture incurred many days after the injection of an animal with radium, Aub and his associates found by counting with a Geiger-Müller counter that there was a higher specific activity in the callus than in cortical bone, and interpreted this as evidence of hot-spot migration. The explanation of these results and those of the present experiment, which are analogous, does not require the hypothesis of hot-spot migration. All that is necessary is that callus be formed with the same specific activity as that of the serum during the relatively short period of deposition, at a time when the serum specific activity is higher than the average specific activity of cortical bone. These are the conditions observed in the present experiment. If in one of the dogs of this experiment, a callus had formed at any time up to 100 days after injection with Ca^{45}, the specific activity of callus would be expected to be higher than the average specific activity of cortical bone. However, at some later date the specific activity of serum may be expected to decline to values below the average specific activity of cortical bone and the specific activity of callus formed then would be lower than that of cortical bone.

The following additional points while not germane to the subject of graft tracer experiments, are evident at once from the data given, and merit mention from the point of view of radiation effects to bone by radioactive materials fixed in bone. Dudley and Dobyns measured the radiation-dosage distribution of Ca^{45} deposited in bone using a tech-

nique similar to that described in this paper, but with much lower resolution. Their findings indicated an average ratio between the specific activity of the most active areas in the epiphysis and the least active areas in the cortex of dog bone of approximately 10 to 1. The maximum ratio they observed was 14 to 1. The data on the injected dogs (Table II, *A*) provide a useful comparison with their data. From the present data the ratio occurring within cortical bone averages 20 to 1, but ranges from 12 to 1 to 35 to 1. Because of the normalization of the data to a single dose level, the values for the diffuse component are shown as constants, but it should be realized that the absolute levels of specific activity in all components are therefore proportional to the injected dose. As a result of the higher resolution of the present method, the ratio between hot spot specific activity to diffuse component specific activity is higher, even within cortical bone, than that observed by Dudley and Dobyns, and this ratio may easily be higher than the maximum given above, when resolution is further improved. The specific activity of different hot spots ranges in value from that of the diffuse component to the maximum values reported in Table II, *A* although the quantitative aspects of this variation are not presented in this communication. These findings are of obvious importance in any consideration of optimal or minimal dosage for biological damage due to radiation, whether it be to the whole skeleton or to any localized portion thereof.

SUMMARY

1. Homogenous-bone grafts in dogs were studied by implantation of radioactive bone from donor dogs previously injected with Ca^{45} and by implantation of non-radioactive bone into hosts which were injected with Ca^{45} prior to, during, or after the grafting procedure. Determinations of serum and bone specific activities were made and compared.

2. A procedure for quantitative autoradiography was developed and applied to the analysis of cross sections of grafted and non-grafted areas.

3. The activity in cross sections of the shafts of the long bones consisted principally of a general diffuse component, the specific activity of which was relatively constant over the 100-day period of study and was proportional to the administered dose. Upon this diffuse component were superimposed a few intense hot spots and often a ring of increased activity in or near the endosteum or periosteum. The hot spots corresponded to individual Haversian systems, and their specific activities ranged up to thirty-five times that of the diffuse component as determined with an autoradiographic resolution of 120 micra.

4. The distribution of Ca^{45} from radioactive grafts were systemic and no preferential transfer of Ca^{45} to callus or nearby bone was detected.

5. In dogs which received non-radioactive grafts and injections of Ca^{45}, the specific activity of the callus was the highest observed anywhere in bone, up to 100 times that of the diffuse component of the host's cortical bone and was strongly dependent on the relation between the time of injection and the time of grafting.

6. The time of calcification of callus occurred predominantly at about the third week after grafting.

7. Relocation of localized deposits of activity without dilution in the whole volume of circulating blood (hot-spot migration) to or from graft areas was not detected in this experiment.

8. The data of this experiment provided two points which are considered pertinent and applicable to the problem of radiation hazard evaluation with respect to radioactive materials fixed in bone. These are the proportionality between the administered dose and the specific activity of the diffuse component and the large ratio between the specific activity of hot spots and that of the diffuse component.

NOTE: We would like to thank Prof. Robley D. Evans and Mr. Joel B. Bulkley of Massachusetts Institute of Technology, and Dr. William Green of the Children's Medical Center for their support and interest in this work. We are also indebted to Miss Marie Helmick, Mrs. Dorothy Kuchta, and Miss Virginia White for the innumerable analyses and measurements and for the development of many details of technique.

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A Comparative Study of Xeroroentgenography and Routine Roentgenography in the Recording of Roentgen Images of Bone Specimens*

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In 1940 and 1944, Carlson obtained patents for a photographic process based on photoelectric rather than photochemical principles. It was called xerography because of the dry nature of the process. Technical details of its roentgenographic counterpart, xeroroentgenography, have been described by McMaster and Wenk, Roach and Hilleboe, and Oliphant. In xeroroentgenography an electrostatic image of the size, shape, and radio density of the interposed object is produced on a xeroplate, which is a metallic plate coated with a semiconductor such as selenium. This image is made visible by placing finely divided powder granules on the charged pattern of the xeroplate. Permanent records are best made by photographic techniques.

Roach and Hilleboe, and Oliphant noted a slight exaggeration of detail in the xeroroentgenogram as compared with that in the routine roentgenogram. Roach and Hilleboe showed that the strength of the electrostatic field was considerably greater at the edge of the charged area than in the center. This was manifest by an increase of powder along

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one side of the boundary of the charged area with a corresponding decrease of powder immediately adjacent to it. Hills, Stanford, and Moore and Oliphant felt that this exaggeration or reinforcement along the dividing line between regions of high and low

FIG. 1-A
Roentgenogram.

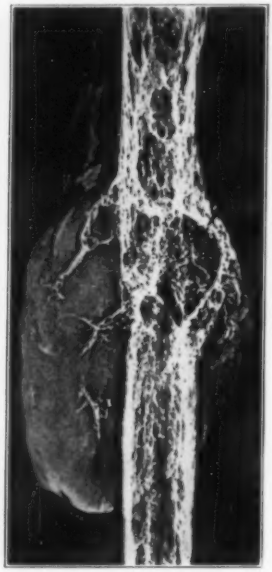

FIG. 1-B
Xeroroentgenogram.

FIG. 1-C
Pathological section.

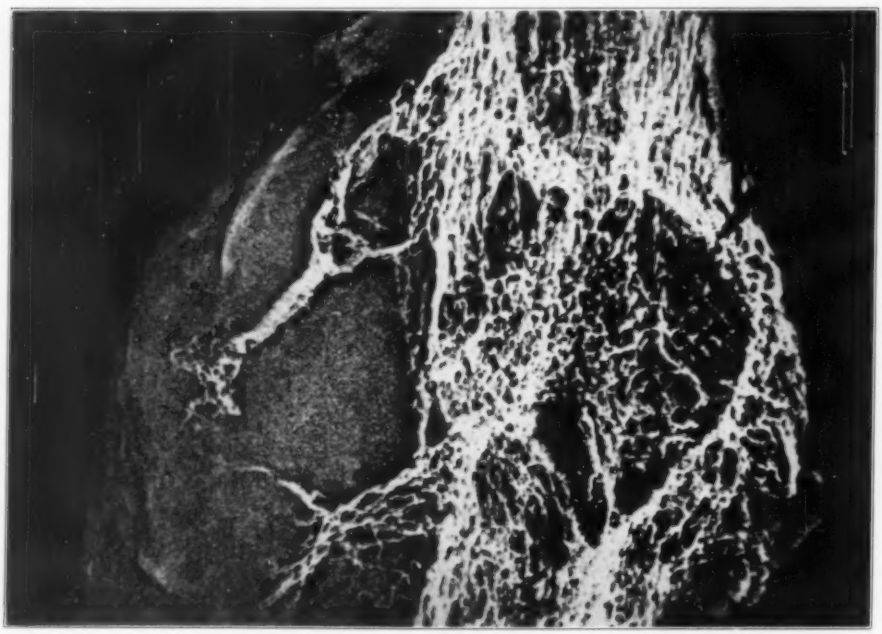

FIG. 1-D
Detail from Fig. 1-B. Note the distribution of the powder at the margins of the trabeculae.

x-ray transparency was a distortion and referred to it as the "pull-in effect". It was this accentuation of contrast that suggested to us that this method of recording roentgen images would be useful in the study of bone specimens and in the study of some bone and joint

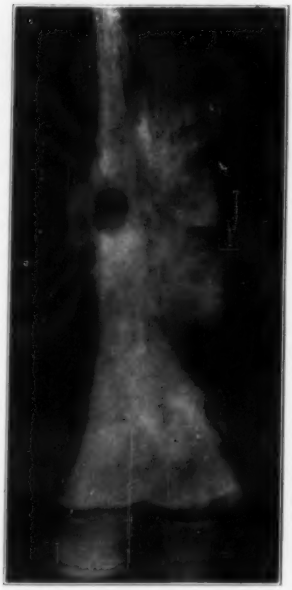

FIG. 2-A
Roentgenogram.

FIG. 2-B
Xeroroentgenogram.

FIG. 2-C
Pathological section.

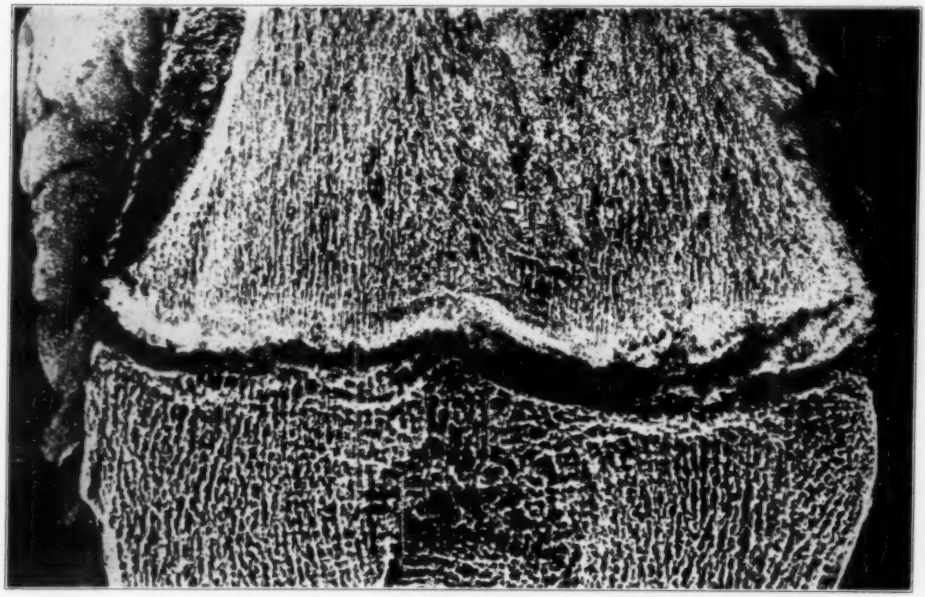

FIG. 2-D

Detail from Fig. 2-B. Note the clarity of the pattern of the tumorous bone in the metaphysis and the obliteration of the trabecular detail in the mid-epiphysis.

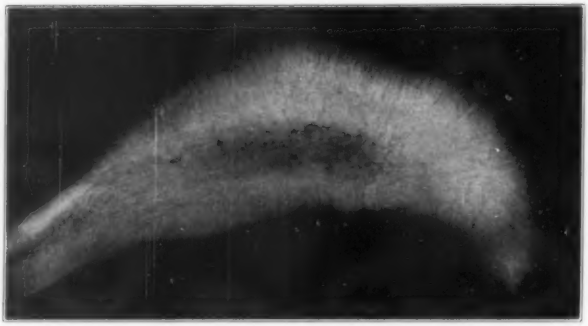

FIG. 3-A

Figs. 3-A and 3-B: As a result of contrast gradation, the xeroroentgenogram shows the pattern of new-bone formation more clearly than does the conventional roentgenogram despite some obliteration of the fine detail.

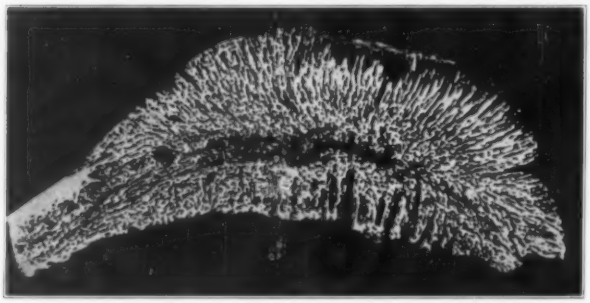

FIG. 3-B

Xeroroentgenogram.

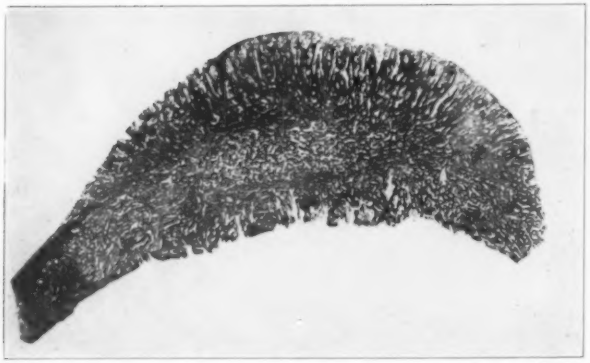

FIG. 3-C

Pathological Section.

disorders in clinical cases.

METHOD

The present study is limited to a comparison of xeroroentgenograms, routine roentgenograms, and pathological sections of bone specimens. Sections measuring one centimeter in thickness were taken from thirty normal and diseased bones and joints. In the making of the xeroroentgenograms and conventional roentgenograms, the exposure was altered in each instance in order to obtain the optimum result for presentation of bone detail. The xeroroentgenograms were recorded photographically by the use of two-by-two inch Type F Kodachrome film; the resulting photographs were enlarged to the exact same size as the routine roentgenograms. By the use of celloidin embedding, microscopic slides were made of all specimens for comparative purposes.

Four characteristic examples of specimens studied are presented in detail to show the results obtained in this comparative study.

CASE 1. A. B., a man fifty years of age, sustained a pathological fracture of the middle third of the humerus. Microscopic examination of the tissue revealed a metatastic hyponephroma. The fracture was treated by means of intermedullary nailing and the administration of 2,000 roentgens in divided doses. The specimen (Figs. 1-A through 1-D) was removed at death. The images obtained in the routine roentgenogram (Fig. 1-A) and in the xeroroentgenogram (Figs. 1-B and 1-D) were of excellent quality. It is apparent in the xeroroentgenogram that wherever there are sharp zones of demarcation, there is increased contrast gradation. A comparison of the two types of roentgenograms as regards the detail along the margins of the fracture line and the intermedullary-nail tract and as regards the pattern of the new-bone formation in the tumor illustrate the differences in the images which are obtained by these two techniques.

CASE 2. N. M., a girl eight years of age, had an amputation of the lower extremity for an osteogenic sarcoma in the distal end of the femur. A section one centimeter thick was taken from the diseased bone (Fig. 2-C). A study of the pattern of the tumorous bone shows clearly the accentuation of local detail obtained in the xeroroentgenogram as compared with the routine roentgenogram (Figs. 2-A, 2-B, and 2-D).

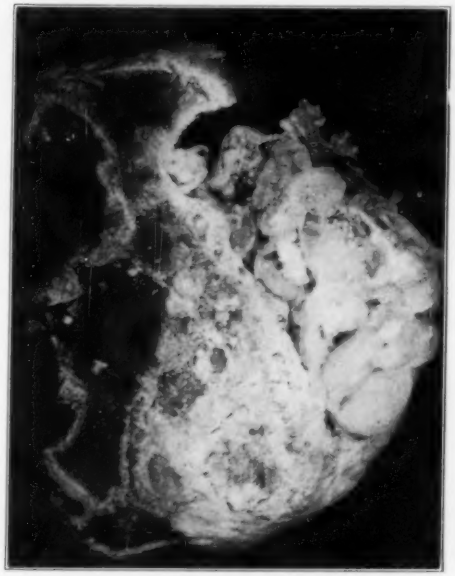

FIG. 4-A
Tumor.

FIG. 4-B
Pathological section.

FIG. 4-C

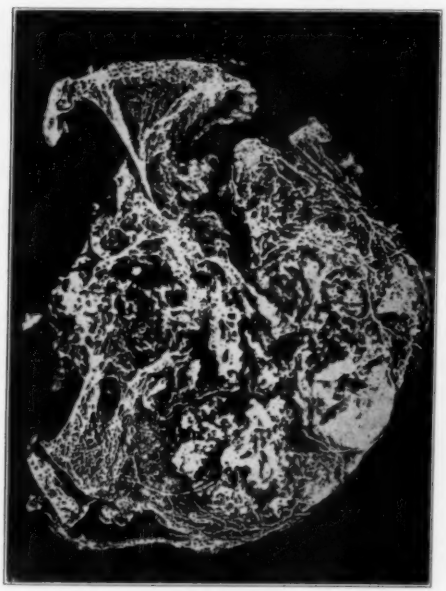

FIG. 4-D

Fig. 4-C: Roentgenogram.
Fig. 4-D: Xeroroentgenogram. Interpretation of the xeroroentgenogram involves an analysis of the powder images of the many soft-tissue details.

In the xeroroentgenogram the osteolytic action of the tumor in the mid-epiphysis is more apparent (Figs. 2-B and 2-D) and such soft-tissue details as the cartilage stand out more clearly (Fig. 2-B).

CASE 3. M. V., a woman forty-one years of age, had multiple lesions in the cranium. Sections made through one of these lesions showed the pattern of new-bone formation in this angiomatous form of meningioma (Fig. 3-C). The coarsening and accentuation of detail in the xeroroentgenogram are quite marked as compared with that in the routine roentgenogram (Figs. 3-A and 3-B). The gross pattern is accentuated with some loss of fine detail. Despite this, the resemblance of the image in the xeroroentgenogram to the pathological section is pronounced.

CASE 4. B. F., a woman thirty-nine years of age, had had a chondrosarcoma of the pelvis for twenty-seven years and had been treated by several courses of roentgen therapy. Following a hemipelvectomy, the arteries of the amputated limb were injected with a radiopaque material. Studies of this specimen showed cartilage, calcified cartilage, tumorous bone, normal bone, fat, fibrous tissue, arteries, and air spaces. The injected arteries stand out more clearly in the xeroroentgenogram than in the conventional roentgenogram (Figs. 4-C and 4-D). The superimposition of soft-tissue detail on the image of the bone pattern in the xeroroentgenogram (Fig. 4-C) illustrates the problem of interpretation which is presented by this new technique.

DISCUSSION

In this study of bone specimens, it was found that there is more pronounced definition and contrast gradation in the xeroroentgenogram than in the routine roentgenogram. This is caused by an increase of powder on one side and a decrease on the other side of the boundary of the electrostatic charge on the xeroplate. In the area of decreased deposit, the fine details of the bone may be diminished or obliterated. This has been termed the "pull-in effect" [4].

The soft-tissue detail is more pronounced in the xeroroentgenogram than in the routine roentgenogram. This feature can be an aid or hindrance, depending on the nature of the tissue under investigation.

In the authors' study artefacts in the form of small spots were often present. These were frequent in xeroplates in which the charge was excessive and in older and more defective xeroplates. Although such artefacts might have obscured certain desired details, they were not easily confused with the bone detail under study. This is a feature that may be eliminated by further technical improvements.

NOTE: We wish to acknowledge the aid of Dr. John W. Pickren and his associates at the Park Memorial Hospital, Buffalo, in furnishing Case 4.

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A Study of Disuse Atrophy of Skeletal Muscle in the Rabbit *†

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The atrophy of innervated skeletal muscle which takes place when it is held at a fixed length by immobilization is a different process than that which takes place in denervated muscle. In atrophy of innervated muscle, there is no fibrillation and no fatty replacement, and the motor end-plates are the last rather than the first structures to be affected. Myostatic contracture develops only in innervated muscle. The rate of atrophy from disuse is similar to, but not so profound as, that in denervation. There is lack of agreement as to the effect of position, the cause of the atrophy, and the possible chemical and histological changes.

This paper reports the results of a study of disuse atrophy of muscle in rabbits. The studies include weight changes, chemical changes, histological observations, and rate of blood flow. Hypertrophy of the tibialis anterior, particularly when the muscle is on tension, has been noted. The chemical changes denote the metabolic nature of both atrophy and hypertrophy. The increased rate of blood flow in both atrophy and hypertrophy falls in line with this point of view.

BACKGROUND

In 1886, Moll found that the principal cause of limited motion at a normal joint after immobilization was contracture of the muscle. He immobilized joints in twelve rabbits for a period of ten days. The limited motion present on removal of the immobilization was relieved by section of the muscles controlling the joint.

Lipschütz and Audova, in 1921, noted that when muscle atrophied after tenotomy and denervation, there were corresponding muscle weight-loss curves.

Lippmann and Selig, in 1928, reported a 20 per cent higher weight-loss course in tenotomy than in denervation, and found little weight loss after immobilization in a cast.

Lange, in 1929, experimented with the importance of tension in muscle and tendon atrophy and regeneration in rabbits. In a series of experimental animals the Achilles tendon and one-third to one-half of the belly of the gastrocnemius were excised. In one group, a silk thread connected the remaining muscle to the calcaneus as tightly as possible; no regeneration occurred. In a second group, with approximately normal tension, regeneration started down the thread of muscle in eight weeks and had the appearance of normal muscle and tendon. In a third series with no tension at all atrophy occurred until the gastrocnemius had nearly disappeared.

Davenport and Ranson, in 1930, studied the histological changes in myostatic contracture produced (1) by the injection of tetanus toxin and (2) by tenotomy. They noted that both methods produced the following changes: (1) increase in diameter of the fiber; (2) more pronounced longitudinal fibrillation; (3) blurred cross striations; (4) dissociation of membrane-holding myofibrils in alignment; (5) wavy contour of some of the fibers; (6) increase in sarcolemma nuclei of a wandering-cell type; (7) light and dark irregularly outlined bands across some of the fibers; (8) slight increase in muscle nuclei in scattered

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fibers; (9) no increase in connective tissue demonstrated histologically, and (10) an irregular histological picture.

Histological changes in muscle are notoriously difficult to evaluate, and disagreement as to the presence or absence of histological changes runs throughout the literature on disuse atrophy and myostatic contracture.

In 1930, Davenport and Ranson defined myostatic contracture as "a condition of permanent shortening in resting muscle which is maintained in the entire absence of nerve impulses, the muscle having acquired, usually as the result of prolonged immobility, a new and shorter resting length." They felt that while adhesions and ankylosis may play a part in the limitation of motion in a joint which has been enclosed for weeks in a plaster cast, these factors are secondary to the shortening of the muscle. After myostatic contracture had once developed, it persisted under anesthaesia and even after section of the motor nerve.

In 1934, Thompson published the results of his experiments with two groups of rabbits. In one group the animals' right hind limbs were flexed to allow weight-bearing and immobilized; in the other group, the animals' limbs were extended and immobilized. There was found to be an average variation in muscle weight of 1.9 per cent. Atrophy of as high as 44 per cent of normal muscle weight was produced. He found that weight-bearing retarded atrophy. Limbs that were extended atrophied 20 per cent, but flexed limbs showed only a 10 per cent reduction of normal muscle weight after six weeks of immobilization.

Chor and Dolkart, in 1939, applied casts to the extremities of monkeys and found a 12.8 per cent muscle weight loss after six weeks. They failed to note any change in the relative amounts of water, nitrogen, and protein, and felt that the atrophy was primarily a reduction in bulk of each muscle cell, the rapid atrophy and fibrosis noted by others being due to circulatory complications.

Eccles, and Knowlton and Hines have noted the importance of activity in preventing atrophy. The disuse atrophy produced by Eccles and by Tower in isolating a lumbar cord segment does not, however, adequately simulate the disuse atrophy of innervated muscle in a cast, despite the lack of fibrillation.

Hines, Thomson, and Lazere, in 1943, noted that there is a common factor of failure to develop tension in atrophies due to denervation, immobilization, and tenotomy, and that this factor might also explain muscle changes in acute inanition. In rats, the maximum isometric tension developed was used as a means of measurement. The loss of strength in acute inanition closely paralleled the loss of total body weight. The loss of strength per unit of muscle-cell phase was found to be much greater in denervated muscle than in fasting muscle undergoing comparable amounts of weight loss. Fibrillary activity was present in denervated muscles but not in the muscles of fasting animals.

Solandt, Partridge, and Hunter, in 1943, produced disuse atrophy by immobilizing the knee and ankle joints of rats with pins. The fresh wet weight of the gastrocnemius-soleus muscle group declined to 58 per cent at the end of twenty-one days. No fibrillations were seen, but the muscles were hypersensitive to intra-arterially injected acetylcholine. There was pronounced initial atrophy but it did not progress as far as atrophy due to denervation. Their findings tend to disprove the belief that fibrillations are caused by a hypersensitivity to acetylcholine.

Eisenhauer and Key, in 1945, found that cats' muscles which had been immobilized in stretched positions showed moderate and persistent disuse atrophy, but the muscles which were immobilized in relaxed and neutral positions showed little consistent effect.

Thomsen and Luco, in 1944, reported experiments on cats. In one series, the gastrocnemius was immobilized in tension and the tibialis anterior correspondingly relaxed (hyperflexion); and in the second series, the reverse of this was done (hyperextension). They noted that the relaxed muscles decreased in weight and the stretched muscles increased in weight during a fourteen-day period. Their work indicated that oedema,

ischaemia, or damage due to compression was not the most important factor in immobilization atrophy.

Ralston, Feinstein, and Inman, in 1952, immobilized the limbs of guinea pigs in extension and in relaxed muscle positions. The results of the study indicated that stretch tends to protect against disuse atrophy.

Summers and Hines, in a paper published in 1951, also noted that tension of the muscle, or at least immobilization in its stretched position, protected against disuse atrophy since the weight and strength loss was least in the gastrocnemius and soleus when held in this position.

Imig and his associates, in 1953, using an electromagnetic-flow meter, found that there was increased blood flow in the immobilized limb and that the increase was similar whether the muscle was stretched or shortened.

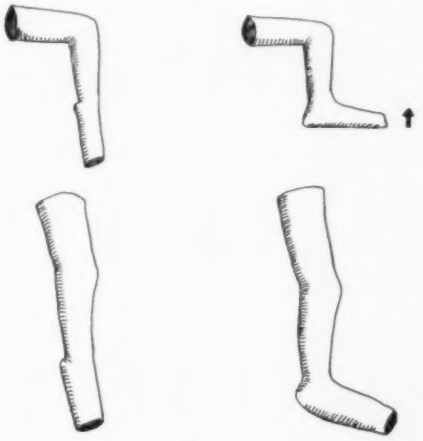

FIG. 1

The positions of the right hind limb of the rabbit when immobilized in plaster cast.

WEIGHT CHANGES

A study of the wet weights of the tibialis anterior and gastrocnemius muscles revealed very definite differences between the two muscles and shed some light on the effect of position.

Method

White, male rabbits weighing between two and five kilograms were used for the study. They were fed a standard laboratory diet with greens and carrots added twice weekly.

The animals were anaesthetized with nembutal, the legs were padded with sheet wadding, and full-limb plaster casts were applied over the wadding. Four basic positions of immobilization were used (Fig. 1). In one group, the knee was flexed at a right angle; the ankle was extended in some and flexed in others. In a second group, the knee was extended, and, as before, the ankle was extended in some and flexed in others.

The animals were kept in their casts for periods varying from one to ten weeks. The animals whose casts were not intact or who had circulatory problems were discarded.

At stated intervals selected animals were killed with nembutal. The tibialis anterior and gastrocnemius were immediately removed from both the immobilized and the free limbs. The muscles were weighed at once on a Roller-Smith balance. The weight of the immobilized muscle is given in terms of per cent of the control (Table I).

The animals whose limbs were immobilized in the flexed position were able to get about their cages quite well using the immobilized limb for locomotion. Those with knee and ankle extended in plaster had difficulty moving about and dragged the limb behind them instead of using it.

Results

The muscles of the right and left sides from twelve normal animals were weighed and were found to agree within 6 per cent. This has also been the experience of other authors using rabbits for similar studies. Langley, in 1916, reported 4.5 per cent, and Lipschütz and Audova, in 1921, reported 6 to 7 per cent agreement between the two sides.

The results in forty-one animals whose limbs had been immobilized are reported. Figure 2-A shows the normal tibialis anterior and gastrocnemius from an animal's two

TABLE I

CHEMICAL ANALYSIS

Number	Time Immobilized	Body Weight Grams		Wet Weight Grams		Per cent H_2O	Milligrams per 100 Milligrams Wet Weight	
				Gastrocnemius	Tibialis Anterior		Glycogen	Creatinine
230	11 days	1,910	Left	7.7777		78.87	380.0	442.7
					1.9045	75.68	400.0	398.6
			Right	6.7484		75.32	315.2	392.9
					2.0913	74.15	522.0	435.2
232	14 days	2,105	Left	8.6914		76.54	490.8	400.2
					2.0821	76.36	480.2	385.0
			Right	6.7560		76.72	462.0	310.2
					3.5078	83.54	526.2	462.2
219	14 days	3,599	Left	13.1314		77.49	699.4	470.7
					3.3502	74.82	653.2	460.6
			Right	12.9594		lost	669.1	473.6
					4.4983	78.53	lost	595.5
218	16 days	2,648	Left	9.9235		75.26	560.0	436.8
					2.9524	75.78	550.6	402.6
			Right	6.9340		75.44	493.2	344.2
					3.1846	77.73	699.2	499.7
220	16 days	2,045	Left	7.7616		75.30	515.1	322.0
					2.0160	75.54	515.2	299.9
			Right	6.3231		74.78	486.2	278.6
					2.7461	77.25	641.2	438.8
237	17 days		Left	11.8097		75.94		
					3.9499	75.37		
			Right	10.1355		75.36		
					3.7948	76.24		
221	18 days	2,290	Left	10.9980		76.49	555.0	463.0
					3.0666	76.70	514.6	414.2
			Right	8.9149		76.10	548.2	388.9
					5.0058	79.74	577.2	460.2
222	18 days	2,295	Left	11.1890		74.86	538.2	399.2
					3.4739	75.80	526.3	358.5
			Right	9.7062		75.49	514.6	308.6
					4.6563	77.41	542.0	477.7

225	28 days	2,390	Left	9.4579	2.6667	76.03	lost	541.2
						76.37	lost	489.4
			Right	7.8522	2.9767	75.32	lost	776.2
						78.67	lost	523.6
235	28 days	2,390	Left	10.2981	2.7544	76.40	516.6	448.2
						75.78	518.2	441.6
			Right	7.6936	2.7958	74.96	402.1	329.2
						76.56	533.3	452.2
229	28 days	1,790	Left	6.5723	1.3277	79.48	499.6	381.7
						77.51	485.6	356.4
			Right	4.6335	1.6975	77.05	262.0	302.2
						76.92	500.2	441.9
236	28 days	2,495	Left	11.2466	3.0249	74.75	lost	537.6
						74.79	504.2	506.9
			Right	7.9976	3.3521	77.36	411.8	488.0
						74.64	595.3	542.8
169	35 days		Left	9.8251	1.6775	75.78		
						76.80		
			Right	5.2353	1.7196	74.70		
						76.38		
170	35 days		Left	8.8363	1.6255	76.58		
						77.05		
			Right	7.1106	2.5908	74.01		
						77.35		
228	37 days	2,534	Left	11.1888	3.0974	76.26	lost	470.2
						76.50	483.2	469.3
			Right	8.6845	3.4755	76.32	499.3	391.1
						75.37	lost	466.2
269	38 days		Left	13.0335	2.7420	74.71		
						76.59		
			Right	9.6910	2.9136	74.90		
						76.29		
227	42 days	2,683	Left	12.3394	3.2665	75.41	427.0	580.0
						76.05	496.2	550.6
			Right	9.0641	2.9961	75.22	400.2	511.1
						76.28	499.4	552.1

TABLE I (*continued*)

Number	Time Immobilized	Body Weight Grams		Wet Weight Grams		Per cent H_2O	Milligrams per 100 Milligrams Wet Weight	
				Gastrocnemius	Tibialis Anterior		Glycogen	Creatinine
231	42 days	2,200	Left	9.9434		76.04	468.8	514.2
					2.7793	76.43	450.6	395.4
			Right	6.3964		75.42	390.0	381.6
					2.0992	76.42	406.2	510.6
234	42 days	2,495	Left	11.2466		75.84	561.2	430.2
					3.0249	76.17	563.2	414.2
			Right	7.9976		75.44	488.2	368.6
					3.3521	75.66	499.6	463.6
198	49 days		Left	11.1472		78.75	685.2	495.0
					3.2832	74.92	412.6	489.2
			Right	8.4489		72.04	452.2	397.7
					3.9784	75.03	680.2	499.6
226	49 days	2,217	Left	12.3410		75.64	714.2	568.2
					3.6384	75.79	696.1	568.6
			Right	10.8632		76.04	493.3	472.2
					3.2206	73.80	502.6	510.2
214	63 days		Left	9.8766		76.32	400.2	510.2
					2.6025	76.05	310.7	500.1
			Right	8.3961		75.27	268.2	464.0
					3.1116	76.40	452.0	556.7
217	63 days		Left	8.6521		75.95	458.6	355.6
					1.7901	76.04	496.2	342.6
			Right	6.7393		76.57	364.0	241.2
					1.5441	67.35	400.2	309.2
211	77 days		Left	8.1644		75.63	530.6	452.7
					2.0241	76.03	512.2	440.6
			Right	6.4705		70.75	440.2	365.0
					2.3019	77.21	493.3	442.9

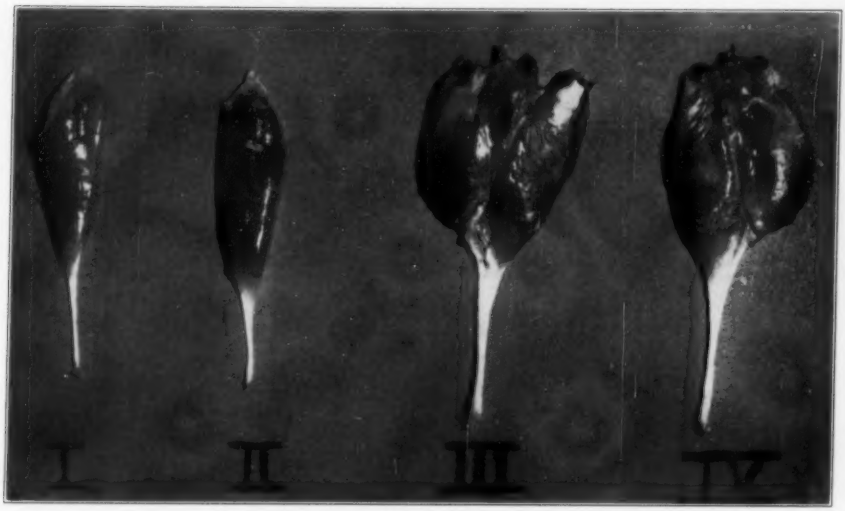

FIG. 2-A

The tibialis anterior and gastrocnemius from both hind limbs of a normal animal.

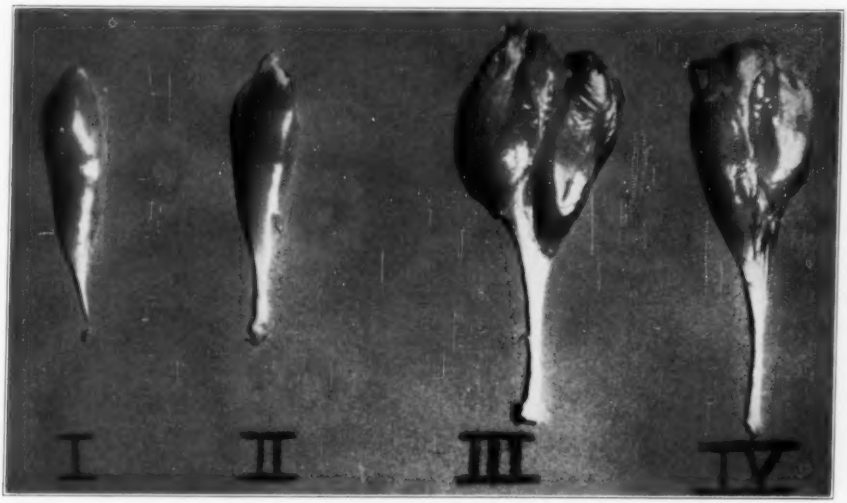

FIG. 2-B

The immobilized tibialis anterior (No. II) shows an increase in size. The immobilized gastrocnemius (No. IV) shows atrophy. All muscles are from the same animal.

hind limbs. Figure 2-B shows hypertrophy of the right tibialis anterior (No. II) and atrophy of the right gastrocnemius (No. IV) occurring in the same immobilized limb.

All the gastrocnemii atrophied as shown in a fairly typical weight-loss curve (Chart I). When the weights of all the tibialis anterior muscles are placed on a graph, as in Chart II, the tendency of the tibialis anterior to resist atrophy and, in fact, hypertrophy, is seen. The gastrocnemius was never observed to increase in weight. The deviation between the means of these two groups is statistically significant; it could have occurred by chance less than once in ten million instances.

Comparison of the tibialis anterior muscles in the stretched and in the relaxed positions revealed the effect of tension (Charts III-A and III-B). The stretched muscle group

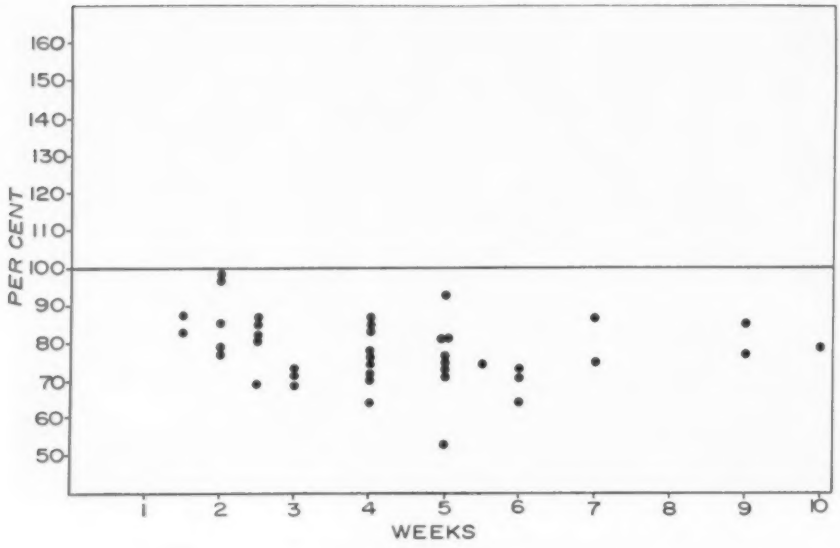

CHART I

The wet weights of the gastrocnemius following immobilization of varying duration are shown. The weights are expressed in percentage of the contralateral limb. Note consistent atrophy.

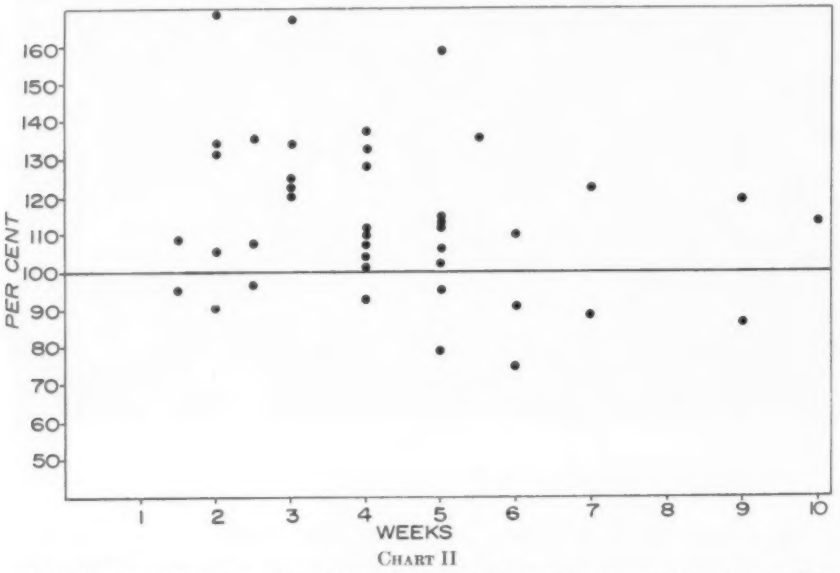

CHART II

The weight of the tibialis anterior which was immobilized in varying degrees of stretch for various periods of time is shown as a percentage result in relation to the contralateral muscle. Note the tendency of the muscle to increase in weight.

hypertrophied to a greater degree than muscles in the relaxed position. The deviation between the means of the stretched and the relaxed tibialis anterior is statistically significant and could have occurred by chance only seven times in ten thousand.

A similar effect was not observed in the gastrocnemius, however. The deviation of the mean between the stretched and the relaxed gastrocnemius is not statistically significant.

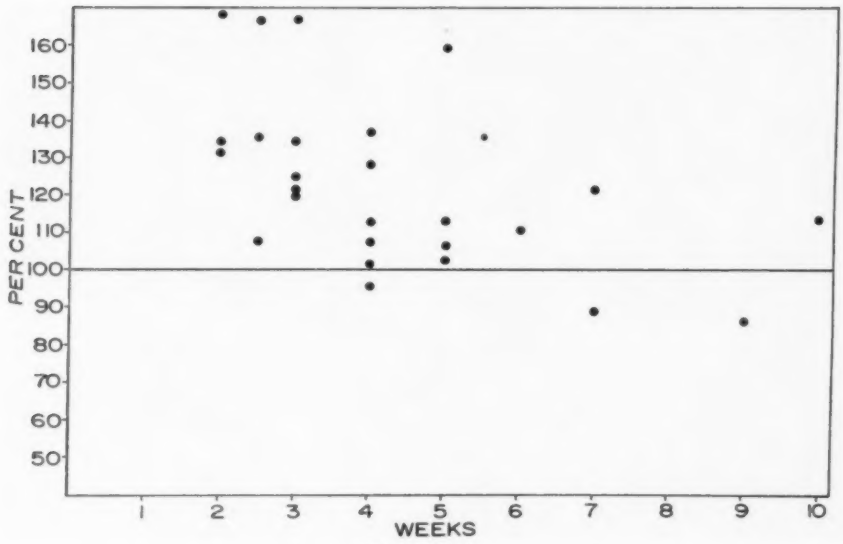

CHART III-A

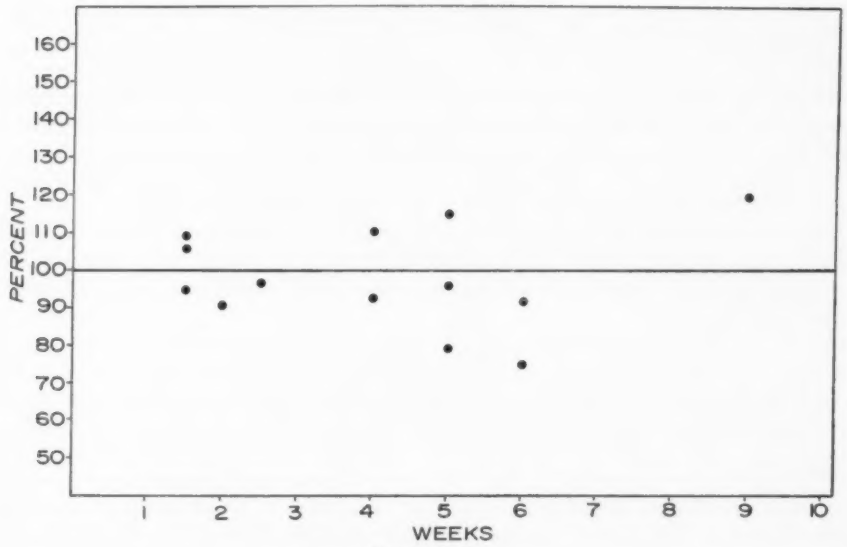

CHART III-B

The wet weights of the stretched (III-A) and relaxed (III-B) tibialis anterior are compared. Note the tendency to hypertrophy occurring early and prominently in stretched muscle.

HISTOLOGY

The tibialis anterior and the gastrocnemius removed from the immobilized limbs and from the control limbs in sixteen animals were studied microscopically.

The sections were cut tangential to the long axis of the muscle for ease in comparison. The fibers are seen in cross section.

There appeared to be no essential change after two weeks of immobilization. After four weeks of immobilization, a lesion could be recognized in the gastrocnemii and in those tibialis anterior muscles which were immobilized in a relaxed position.

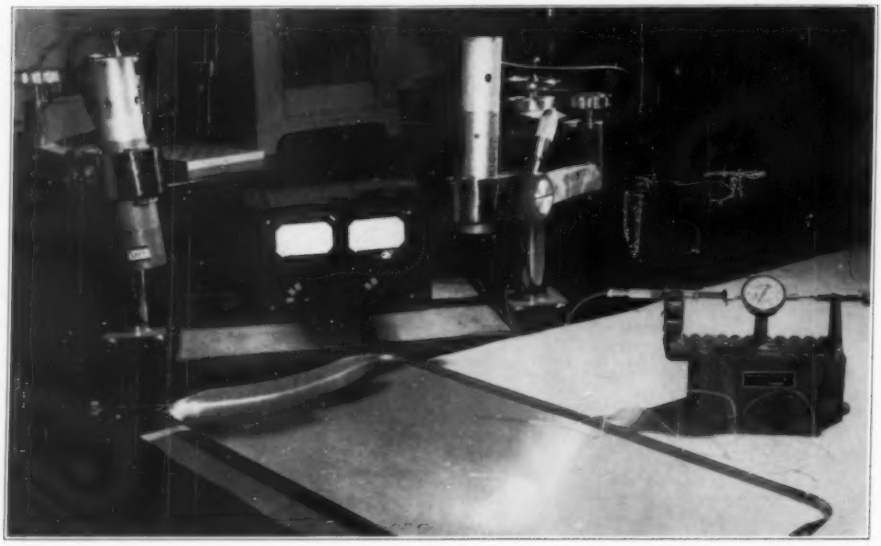

FIG. 3

Laboratory setup for measuring sodium clearance with two independent crystals mounted on adjustable beams and leading to two counting-rate meters. The tandem syringe setup for simultaneous injection is also shown.

This lesion consisted of an increase of sarcolemma cells surrounding the fiber and an occasional isolated fiber which had undergone degeneration, with a number of sarcolemma nuclei filling up the areas previously occupied by the intact fiber.

There was no evidence of fibroplastic process, fatty degeneration, inflammation, or a decrease in fiber size of sufficient degree to be unequivocally recognized.

This increase of sarcolemma cells and occasional fibrous degeneration did not appear in the tibialis anterior muscles immobilized under tension. The gastrocnemius, on the other hand, was the frequent site of this lesion when the muscle had been immobilized four weeks or longer.

BLOOD FLOW

The blood flow in the immobilized rabbit muscle was determined by a method originally reported by Kety in 1949.

Method

With the animal under nembutal anaesthesia, radioactive sodium (Na^{24}) was injected into the muscle on both sides of the animal simultaneously. The sodium was in a dilution of 320 microcuries per cubic centimeter and was injected from tandem syringes in an amount of 0.02 cubic centimeter.

A collimated scintillation crystal was then placed over each injection site. These were sodium iodide, thallium activated crystals nine-sixteenths of an inch in diameter and one-half inch long. There was one and one-quarter inches collimation three-quarters of an inch thick. The crystal was in contact with a RCA 6199 photo multiplier tube with output to a pre-amplifier and thence to a counting-rate meter. Two setups, similar but separate, were used (Fig. 3).

Readings were taken at thirty-second intervals for a ten-minute period. Thereafter, the readings tended to stabilize because of the background of the now circulating sodium.

The animals studied were a group whose limbs had been immobilized in plaster casts

as has been described. The contralateral limb was used as a control and results are expressed in terms of the immobilized limb.

Results

The tibialis anterior muscles in thirteen rabbits were studied at intervals up to ten weeks, and the results are shown in Chart IV. All muscles had an increased rate of sodium clearance on the immobilized side. The increase ranged as high as 39.4 per cent. Although hypertrophy occurred in nine of these animals after four weeks' immobilization, a similar circulatory rate was found in three tibialis anterior muscles which atrophied.

Immobilized muscles in six animals were studied in order to contrast the muscles of the two sides; they were found to agree within 2 per cent.

Sodium-clearance studies were done on the immobilized gastrocnemius in nine animals. The muscles were found to have undergone uniform atrophy. The Na^{24} clearance rate was increased in seven of nine animals. The position of the immobilization did not appear to affect the rate of clearance.

In order to make sure that these findings were not the result of reactive hyperaemia following removal of the cast, the study was repeated the following day in four additional animals. The results were similar.

CHEMISTRY

The right hind limbs of twenty-four white male rabbits, each weighing between 1500 and 3000 grams, were immobilized in padded plaster casts. The positions of flexion at knee and ankle previously described were used. Tissue chemistry studies were performed on the gastrocnemius and the tibialis anterior of both the immobilized and the free limbs. Results are expressed in per cent of the immobilized limb.

As control studies, muscles from the right and left sides in eight normal animals were removed and compared. These results are shown in Chart V.

Analyses were done for water, creatinine, and glycogen content.

Methods

Water: The wet, diluted, and pulverized sample of muscle was dried in an oven at 100 to 105 degrees centigrade for twenty-four hours, cooled in a dessicator for one hour, and weighed.

Creatinine: The method used was similar to the one developed by Folin and Wu. After dissection, the fresh tissue portion was immediately dropped into a fifty cubic centimeter Erlenmeyer flask and weighed with the flask stoppered. Each sample was treated with double normal sulphuric acid stoppered with loose mesh, and autoclaved for forty-five minutes at fifteen pounds per square inch. After cooling, each solution was transferred to a 100 cubic centimeter volumetric flask and treated with double normal sodium hydroxide and 10 per cent sodium tungstate. The mixture should be faintly acid to Congo red and diluted to volume with distilled water. Ten cubic centimeters of a filtrate of this solution was treated with five cubic centimeters of alkaline picrate solution. At the same time, twenty cubic centimeters of a standard creatinine solution was treated with ten cubic centimeters of alkaline picrate. After standing for eight minutes the color comparison was made. For voluntary muscle, a suitable standard will contain 0.8 to 1.0 milligram per twenty cubic centimeters. The color should be read as soon as possible after development and after eight minutes of standing.

Glycogen: The method used was a modification of the procedure devised by Cori. Tissue in one to 1.5 gram amounts was added to a previously weighed test tube containing potassium hydroxide. The unstoppered tube was placed in a boiling water bath for forty minutes. When the tissue was entirely dissolved, the tube was removed from the bath and centrifuged. It was decanted into a fifteen-million centrifuge tube previously marked

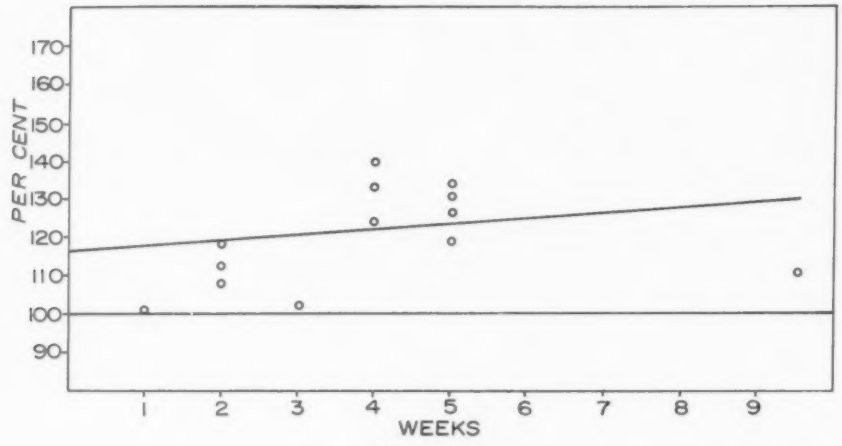

CHART IV

The increased sodium clearance from the tibialis anterior is expressed in terms of the unimmobilized hind limb.

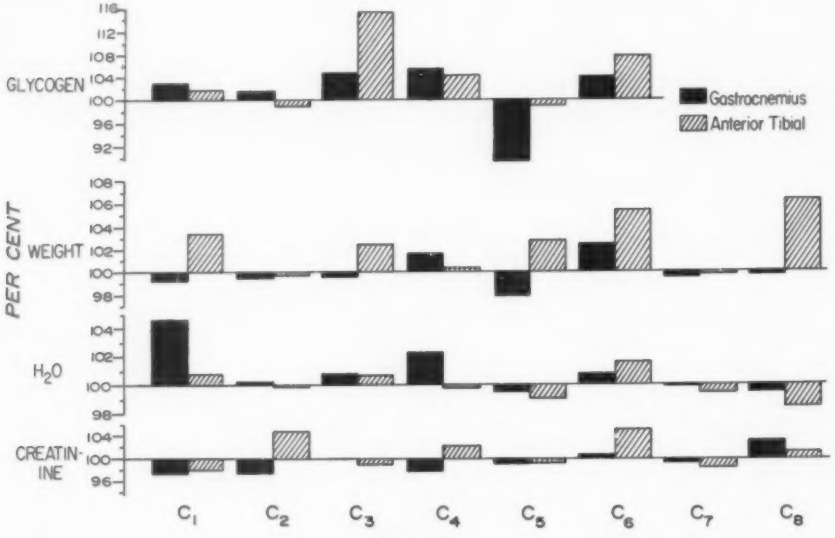

CHART V

Control studies of glycogen, creatinine, weight, and water done in eight normal animals. Note that the scale has been magnified for the controls, when compared with Chart VI. The results are expressed as percentages with the value for the right immobilized limb placed over the value for the left unimmobilized limb.

at ten milliliters and heated again in a water bath. It was then removed and six milliliters of 95 per cent alcohol was added and mixed with a glass rod. The centrifuge tube was returned to the water bath until the liquid in the tube began to boil; then it was removed and cooled.

It was centrifuged, decanted thoroughly, and drained. The precipitate should be nearly white.

For hydrolysis of glycogen the tissue was heated for two to two and one-half hours in a boiling water bath after adding five milliliters of three-fifths normal hydrochloric acid. This was cooled and was diluted to the ten-milliliter mark.

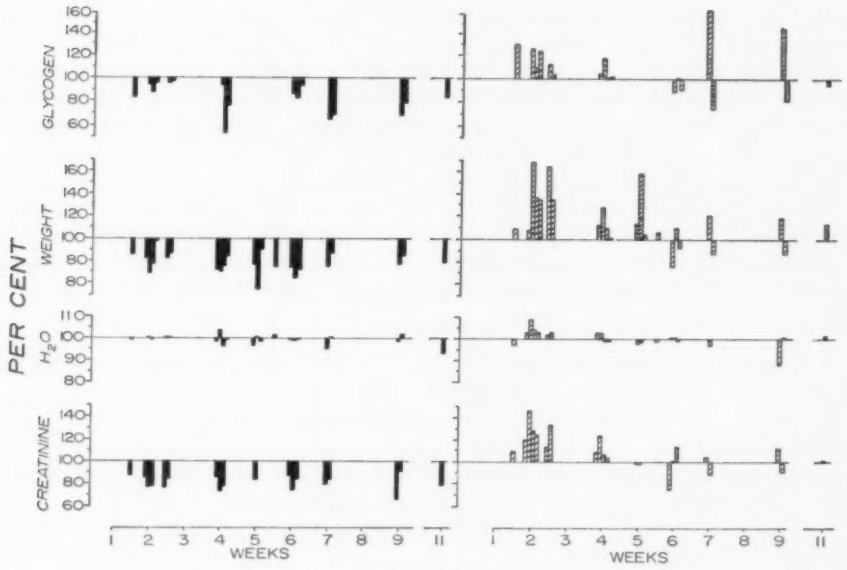

CHART VI

Results in immobilized animals expressed as a percentage with the value for the immobilized limb placed over the value for the free limb. The gastrocnemius values are solid bars, the tibialis anterior values are hatched bars. The graph for water content has been magnified in relation to creatinine and glycogen content and weight, in order to make results visible. Water content remained essentially constant, the creatinine and glycogen contents tending to follow the weight changes. This graph was derived from the results recorded in Table I.

The amount of glucose then present was determined by micro methods of analyzing for the reduction of an ion, and compared to the amount achieved by a standard solution of glucose.

RESULTS

The mineral results of the tissue chemistry studies are shown in Table I. These results were converted into percentages by placing the value for the right limb above the value for the left. (The right limb was always the one immobilized.) These results are diagrammed in Chart VI.

A weight increase in the tibialis anterior is shown to have a corresponding increase in glycogen and creatinine with the water values unchanged. Atrophy of the gastrocnemius reveals a corresponding fall in glycogen and creatinine without a fall in water content.

DISCUSSION

The significance of this study appears to lie in two areas. The evidence marshalled by chemical and histological studies of tissue and by studies of the rate of blood flow indicate the metabolic nature of atrophy and hypertrophy rather than a change in hydration or fat content. This concept of the metabolic nature of atrophy and hypertrophy suggests the possibility that conceivably either might be altered or controlled in the future.

The difference in response to immobilization between the tibialis anterior and the gastrocnemius is important statistically. The suggestion that this difference is simply due to the animal attempting to struggle out of its cast is not borne out by the actual activity of the animal as observed in the laboratory. The animal with the extended limb merely dragged it behind as it moved about, whereas the animal whose limb was immobilized in a flexed position actually used the limb in progressing. The increased rate of blood

flow does not necessarily indicate a greater blood volume; its interest lies in the increase of both atrophy and hypertrophy.

What causes hypertrophy rather than atrophy is not clear. It is true that the gastrocnemius could not be kept at a fixed length in the cast as successfully as the tibialis anterior. This was due to the poor control of the immobilized thigh as compared with the control of the calf and foot by the plaster. The more completely immobilized the muscle was, the more thoroughly hypertrophied it became.

The different modes of action of the tibialis anterior and gastrocnemius which have been previously reported by the author, may contribute to the understanding of the different reactions of these muscles in immobilization. It should be noted that no conclusions in relation to man have been established by the study reported in this paper.

CONCLUSIONS

1. There is a fundamental difference in the reaction to immobilization of the tibialis anterior and the gastrocnemius in the rabbit.

2. There is an increased blood flow in both atrophy and hypertrophy of skeletal muscle in this animal.

3. Atrophy and hypertrophy appear to represent a change in intracellular constituents without change in the water content of the muscles studied.

4. Tension appears to protect against atrophy, in so far as the tibialis anterior is concerned in the rabbit.

5. Both atrophy and hypertrophy of skeletal muscle in the rabbit appear to represent a metabolic change.

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(*Continued on page 624*)

Histological Investigation of Bone Transplants in Immunologically Prepared Animals*†

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There is little doubt that autogenous transplants of bone, or of any other tissue, are better accepted by the host than other types of transplants [1, 3, 6, 7, 8, 9, 12]. There is experimental evidence that the periosteum of autogenous transplants survives and proliferates, that the proliferation materially aids in the incorporation of the transplant, and that the transplant is eventually replaced by host tissue.

The non-acceptance of homogenous-skin transplants in man is well recognized and much research has been done in an attempt to discover the cause. Despite this work, the subject of acceptance of homogenous and heterogenous bone transplants has been obscured by conflicting reports resulting from the difficulties inherent in histological interpretation and by the apparent acceptance of these transplants by clinical and roentgenographic criteria. There are three well documented types of response to homogenous-bone transplantation in experimental animals:

1. Portions of the homogenous transplant may proliferate, survive, aid in the incorporation of the transplant, and in all ways be the equal of autogenous transplants [12].

2. The homogenous transplant may not produce surviving proliferations but act merely as an inert mechanical framework for replacement by host tissue.

3. The homogenous transplant may be rejected by the host and destroyed without aiding the repair in any degree. There have been frequent histological observations of homogenous-bone transplants evoking an enveloping fibrous-tissue reaction, although no evidence has been brought forth to explain this. These experimental results have been observed in animals of low-order immunological complexity.

The introduction of any foreign protein of antigenic capacity into an animal evokes an inflammatory response characterized histologically by the formation of granulomatous cell masses composed of polymorphonuclear leukocytes, eosinophils, lymphocytes, plasma cells, and giant-cell phagocytes, enmeshed in a framework of fibroblasts and capillaries. In the acute phase, the polymorphonuclear cells and the eosinophils make up the majority of the inflammatory reaction, and in the later stages the lymphocytes and fibrous connective-tissue cells predominate. This reaction is presumed to be dependent upon the production of antibodies by the host and occurs at the site of antigen localization when sufficient antibodies have been produced. In some species, this reaction has been shown to be related to identifiable precipitating antibodies in the serum. This defensive mechanism of the animal in which the antigen-bearing material is isolated and destroyed is thought by some to be the reason why homogenous-tissue transplants fail [8]. It has been compared to a delayed sensitivity or Arthus-like phenomenon. This phenomenon, according to Rich, is an antigen-antibody reaction which directly affects the vascular endothelium at the site of antigen localization [14]. Local necrosis follows as circulation to the antigen-bearing area is obliterated. While this reaction is difficult to evaluate precisely, it has been shown to be related in intensity both to the amount of antigen introduced and to the titer of circulating antibody [10]. Immunological studies have shown the presence of circulating antibodies against homogenous-bone transplants in rabbits [2]. Transplanted whole dog bone also appears to act as an antigen [4].

The experiments reported here were done to investigate by histological methods

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the response of rats to various types of bone transplants after the animals had been sensitized to the transplants.

METHODS OF INVESTIGATION

Transplants of full circumference pieces of the femoral shaft were obtained by means of a motor saw with a dental blade, from female Sprague-Dawley rats weighing 200 to 250 grams. The transplants consisted of the middle third of the femur with its periosteum. They were placed in the host animals from which corresponding segments of femoral shaft had been removed. Immobilization was obtained by means of an 0.45-centimeter Kirschner wire passed through the entire medullary canal (Fig. 1).

FIG. 1

Fig. 1: The Kirschner wire serves as an intramedullary pin to immobilize the centrally located transplant against the proximal and distal portions of the host femur.

As controls, autogenous preparations were made by exchanging the mid-sections of the left and right femora in the same animal. Homogenous preparations were made by exchanging the mid-sections from the left femur in two unselected animals. Presensitized homogenous preparations were made in two ways. In one method, a second set of transplants was exchanged between the pairs of animals previously used for the homogenous preparations. Mid-sections of the right femur were exchanged at an interval of fourteen to twenty-one days after the entire homogenous preparation of the left femur had been removed by hip disarticulation. The other method was accomplished by establishing in two unselected animals a parabiotic union. Femoral mid-sections were exchanged between the two lateral femora of these animals twenty-one to twenty-eight days after parabiosis.

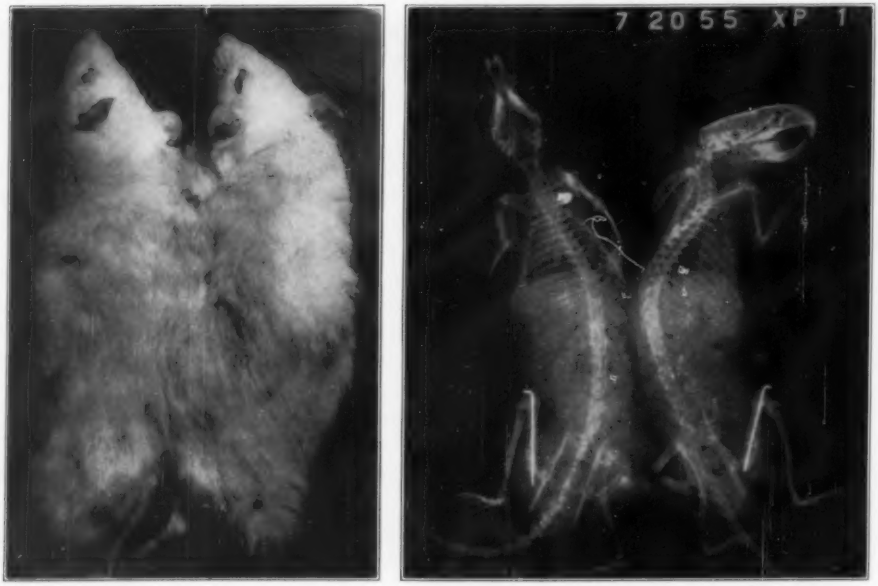

FIG. 2
Parabiosis

TABLE I
NUMBER AND TYPE OF PREPARATIONS STUDIED

Time	Type			
	Autogenous	Homogenous	Presensitized Homogenous	Parabiotic
4 hours	1	4	0	0
24 hours	2	2	2	2
3 days	2	2	2	2
5 days	3	3	3	3
7 days	3	3	3	4
15 days	3	7	4	3
30 days	3	8	5	4
45 days	3	7	4	3
60 days	3	7	5	3
75 days	3	5	4	2
90 days	3	6	4	2
105 days	3	5	5	2
120 days	3	7	4	4
Totals	35	66	45	34

Preparations were made from specimens obtained four hours, twenty-four hours, three, five, seven, fifteen, thirty, forty-five, sixty, seventy-five, ninety, 105, and 120 days after transplantation. Histological sections were made of the entire length of the femur. They were cut along the axis of the pin tract in order to secure a uniform host-to-transplant relationship for study.

Rats were used for the experiment because they are the most antigenically complex animals in which prolonged survival follows parabiosis. Full circumference segments of the femoral shaft were used as transplants to provide ease of internal fixation, as an aid to identifying the reactive bone from the transplant histologically, and to provide an adequate amount of antigen. The same pairs of animals were used for homogenous preparations and second-set presensitized homogenous preparations, in order to ensure uniform identity of antigenicity in the transplants. This repetition of exchange transplantation between the same animals permitted an evaluation of the validity of histological interpretation.

Parabiosis as a method for physiological study has been well reviewed [5]. A parabiotic union consists of a common skin wall and abdominal cavity with a functioning cross circulation produced in two previously independent animals (Fig. 2). The mortality rate from this surgical procedure, excepting immediate postoperative deaths, was 65 per cent. Death resulting from immunological incompatibility occurs between the tenth and twentieth days after union. Rats which survive this period may then survive for more than one year. This survival of mutually immunologically antagonistic members of the union is theoretically explained on the basis of an insufficient degree of immunological response to cause fatal intoxication despite a freely patent cross circulation. The following immunological features of parabiosis have been shown experimentally:

1. That antibodies can pass through the cross circulation from one side to the other in the union;

2. That active acquired immunity (hypersensitivity) may be transferred from one side of the union to the other;

3. That the members of the union form specific antagonistic antibodies against each other which may result in death of one of the partners;

4. That although exchange homogenous-skin transplantation will succeed in intensely inbred animals, repetition of the exchange homogenous-skin transplantation fails after parabiosis has been done in these same animals. In the light of these findings, parabiosis serves as a useful method to prepare, immunologically, animals in order to determine the effect of circulating tissue-specific antagonistic antibodies against homogenous-tissue transplants.

Table I shows the number and type of preparations studied.

RESULTS OF HISTOLOGICAL INVESTIGATION

Four Hours

Unorganized hematoma filled the transplant-host junctions. Neither the transplant nor the traumatized ends of the host cortical bone showed any autolysis of their osteocytes. There was no proliferation of the periosteal cells of the host or of the transplant. The periosteum was absent for a short distance on either side of the host-transplant junction. A thin zone of leukocytes enveloped the transplant and the adjacent ends of the host bone.

FIG. 3-A

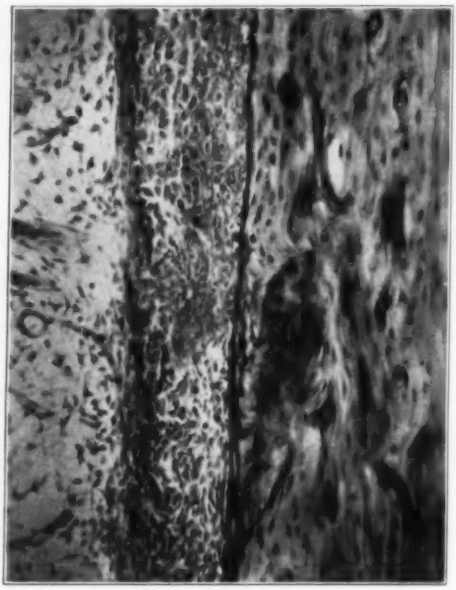

FIG. 3-B

Fig. 3-A: Seven-day autogenous: The low-power frame shows the periosteal proliferations of the transplant along the margin of the cortex in the lower half of the frame, the clumping of inflammatory cells at the transplant-host junction, and the periosteal proliferation of the host cortex in the upper half of the frame.

Fig. 3-B: The high-power frame shows the necrotic transplant with its surviving periosteal proliferations and the more peripheral zone of reparative fibroblasts and capillaries from the host.

Twenty-Four Hours

The hematoma about the transplant-host junctions showed early organization. There was an increase in the number of inflammatory cells about the transplant. They were particularly dense at the transplant-host junctions where they formed clumps. At a distance from the transplant-host junction, the untraumatized periosteum of the host showed proliferation of its cells preliminary to initiating the repair processes of the host. The transplant showed no proliferation of its surviving periosteum. Patches of empty lacunae in the transplant cortex and in the traumatized ends of the host cortex denoted osteocyte autolysis. At this time, there was no difference in appearance between the various types of preparations.

Three Days

The hematoma was well organized. The periosteal proliferations of the host were eight to twelve cells in thickness and extended along the shaft of the femur towards the transplant-host junction. The transplants showed an early periosteal proliferation two to four cells in thickness. This proliferation was less evident in proximity to the transplant-host junction. A definite zone of fibroblasts and inflammatory cells had formed about the transplant and the denuded ends of the host bone. This zone separated the periosteal proliferations of the transplant from the enveloping soft tissues of the host. The clumps of inflammatory cells at the transplant-host junctions were prominent. In the majority of specimens, the transplant and the traumatized cortex of the host were devoid of osteocytes, although here and there intact cells could be seen. A seam of dead bone extended the entire length of the femur and lined the tract produced by the intramedullary pin. This seam was the thickness of one Haversian system and was apparently produced by the

FIG. 4-A

FIG. 4-B

Fig. 4-A: Seven-day homogenous: The low-power frame shows the periosteal proliferations of the transplant in the lower half of the frame, a small collection of inflammatory cells at the transplant-host junction, and the larger, more advanced periosteal proliferation about the host in the upper half of the frame.

Fig. 4-B: The high-power frame shows the dead transplant with a few viable-appearing osteocytes in the peripheral seam of bone, the periosteal proliferation, and the peripheral zone of reparative fibroblasts and capillaries.

trauma attendant upon the introduction of the pin. Again, no difference between the various types of preparations was evident.

Five Days

There were well formed osteoid bars in the proliferating periosteum of the host. This reactive new bone extended almost to the transplant-host junction. The transplants had eight to ten cell thick periosteal proliferations about them. The oedematous zone of fibroblasts and inflammatory tissue which was seen encasing the transplant in earlier preparations was less oedematous and contained fewer acute inflammatory cells. This zone was laced with embryonic capillaries which extended from the host into the periphery of the zone. These embryonic vessels were oriented at right angles to the long axis of the transplant. This peripheral inflammatory zone not only surrounded the transplant but also enveloped the traumatized ends of the host bone. Only occasional osteocytes were seen in the cortex of the transplants. The traumatized cortex of the host and the medullary seam of dead bone were well demarcated by empty lacunae. The clumps of inflammatory cells at the transplant-host junctions were still very prominent, although they contained fewer acute inflammatory cells and more lymphocytes. In the presensitized homogenous preparations, there were increased numbers of inflammatory cells about the transplant.

Seven Days

The periosteal proliferations of the host now extended to the transplant-host junctions and were thickened at this point. These proliferations contained fairly heavy bars of osteoid. The periosteal proliferations which arose from the transplant contained im-

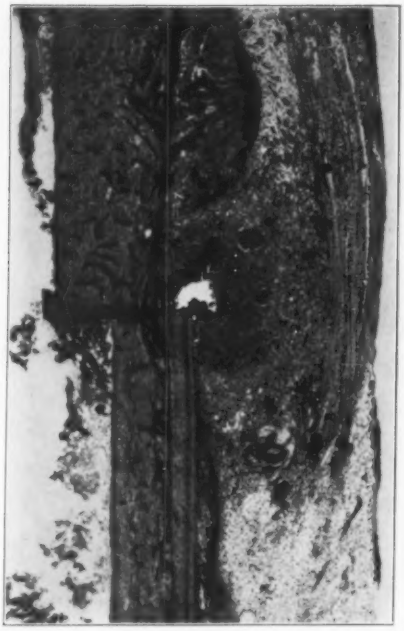

FIG. 5-A

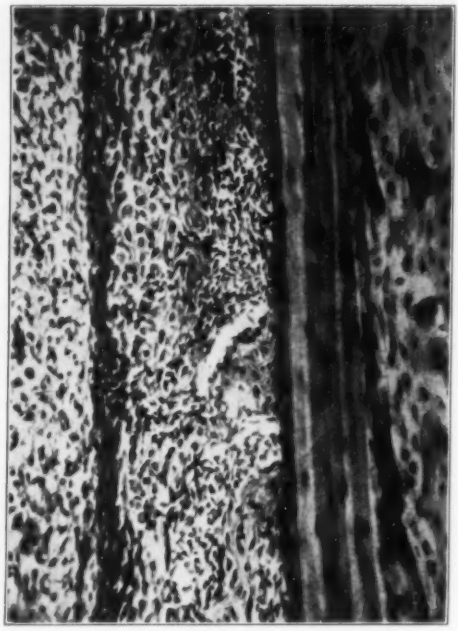

FIG. 5-B

Fig. 5-A: Seven-day presensitized homogenous: The low-power frame shows the transplant with its periosteal proliferations in the lower half of the frame, a small collection of inflammatory cells at the transplant-host junction, and the more advanced host periosteal proliferation about the host cortex in the upper half of the frame.

Fig. 5-B: The high-power frame shows the necrotic transplant, the periosteal proliferations containing immature bars of osteoid, and the more peripheral zone of fibroblasts and capillaries of the host.

mature bars of osteoid. The clump-shaped collections of inflammatory cells at the transplant-host junctions were as evident as they appeared in preparations forty-eight hours younger. Both the traumatized ends of the host and the transplant contained scattered intact osteocytes. These apparently surviving cells appeared to be confined with isolated Haversian systems. There was no destruction of the necrotic bone. The zone of inflammatory cells about the transplant was more mature, had patent capillaries, and showed a predominance of fibroblasts. There was no distinguishing features between the different types of preparations seven days after transplantation (Figs. 3-A through 5-B).

Fifteen Days

The autogenous preparations showed that the previously observed bars of osteoid had matured into bony trabeculae in the periosteal reactive bone of the host. The spaces between these more mature trabecular bars were free of the active young osteoblasts that had filled them in earlier preparations, and they contained active hematopoietic marrow cells. The periosteal proliferations of the transplant contained well formed bars of osteoid. This new reparative bone extended along the free margin of the transplant and was separated from the periosteal reactive new bone of the host at the transplant-host junction by a seam of cartilage. The clumps of inflammatory cells previously seen at the transplant-host junction were absent. The zone of fibroblasts which, before, had separated the periosteal new bone of the transplant from the enveloping soft parts of the host was greatly diminished. There was early destruction of both the transplant and the traumatized host cortices, with invasion of the empty Haversian canals by buds of capillaries and embryonic mesenchymal cells (Figs. 6-A and 6-B).

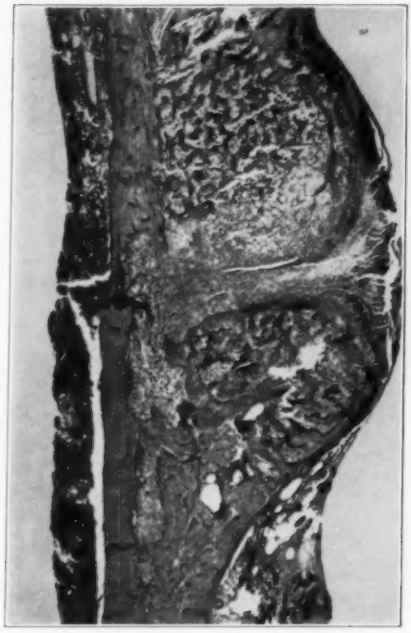

FIG. 6-A

FIG. 6-B

Fig. 6-A: Fifteen-day autogenous: The low-power frame shows similar amounts of fast-maturing periosteal proliferations about both the lower transplant and the upper host cortices with early cartilagenous union between them.

Fig. 6-B: The high-power frame shows the trabecular periosteal new bone of the transplant proliferations and the beginning destruction of the necrotic transplant cortex.

In the homogenous, presensitized homogenous, and parabiotic preparations, the periosteal reactive bone of the host was as mature as the host proliferations in the autogenous preparations. However, the transplant proliferations were almost completely absent. The few scattered areas of surviving transplant proliferations had matured. In general, however, instead of periosteal proliferations, these transplants were encased in a cellular bed composed of fibroblasts, lymphocytes, and large eosin-staining cells containing from two to ten nuclei. Destruction of the transplants varied in degree. Invasion of Haversian canals and reparative processes were minimal. There was less cellular inflammatory reaction about the homogenous transplants than about either the presensitized homogenous transplants or about the parabiotic transplants (Figs. 7-A through 9-B).

Of the seven homogenous preparations studied, four showed a major inflammatory response as described and illustrated. Two of these seven preparations showed a decided decrease in the amount of inflammatory cells. There was no proliferation of the transplant periosteum. In one of these homogenous preparations there was no evidence of inflammation, there was proliferation of the transplant periosteum, and the preparation in every way resembled the autogenous preparations.

Thirty Days

The trabecular reactive bone of the host was united to the mature reactive bone of the autogenous transplants by a thin line of cartilage cells, which was immediately peripheral to the transplant-host junction and which dipped down into the small gap between the transplant and the host cortices. There were blood vessels in the old Haversian canals of both the necrotic bone of the host and the transplanted bone. These canals

FIG. 7-A

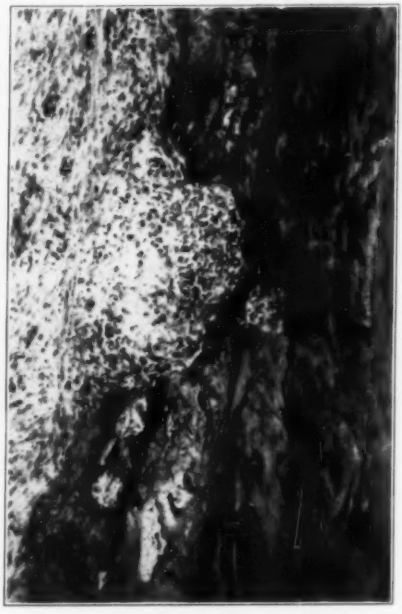

FIG. 7-B

Fig. 7-A: Fifteen-day homogenous: The low-power frame shows the transplant in the lower half of the frame surrounded by inflammatory tissue with its periosteal proliferation maturing but dying off, and the rapidly maturing host periosteal new bone being rebuffed at the transplant-host junction by the inflammatory tissue.

Fig. 7-B: The high-power frame shows the destruction of the periosteal proliferations of the transplant and the inflammatory cells about them.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Fifteen-day presensitized homogenous: The low-power frame shows the transplant in the lower half of the frame enmeshed in inflammatory tissue and the expanding host periosteal new bone being rebuffed by this tissue.

Fig. 8-B: The high-power frame shows the inflammatory cells about the necrotic transplant extinguishing the maturing periosteal proliferations.

FIG. 9-A

FIG. 9-B

Fig. 9-A: Fifteen-day parabiotic: The low-power frame shows the transplant in the lower half of the frame surrounded by inflammatory tissue and the host cortex in the upper half with its periosteal new bone being rebuffed at the transplant-host junction by the inflammatory tissue.

Fig. 9-B: The high-power frame shows the necrotic transplant surrounded by inflammatory cells.

were lined with seams of new living bone. There was no inflammatory reaction about the autogenous transplants.

The homogenous preparations showed the same amount of host periosteal reactive bone as the autogenous preparations, but the transplants were separated from this reactive bone by a zone of fibroblasts, lymphocytes, and scattered giant cells. There was active destruction of the homogenous transplant with feeble attempts at replacement peripherally. The periosteal proliferations of the transplant persisted in some areas, but the transplant was prevented from uniting with the host reactive bone by the enveloping bed of inflammatory tissue.

Of the eight homogenous preparations studied, five were as described. Two of these preparations showed no evidence of an inflammatory reaction. The transplants lay within a bed of embryonic mesenchymal cells and capillaries. Periosteal reactive new bone from the host partly bridged the host-transplant junction. There was no periosteal proliferation about the transplants. One of the homogenous transplants showed no inflammatory reaction and there was mature trabecular reactive bone about the transplant which was united to the periosteal reactive new bone of the host by a thin line of cartilage cells. This preparation was histologically indistinguishable from the autogenous preparations.

The presensitized and parabiotic preparations were similar. In these preparations the periosteal new bone of the host approached the transplant-host junction from either end, but was rebuffed by a thick zone of fibroblasts, lymphocytes, giant cells, and occa-

FIG. 10-A

FIG. 10-B

Fig. 10-A: Sixty-day autogenous: The low-power frame shows the transplant in the lower half of the frame surrounded by matured periosteal new bone that is united to the periosteal new bone of the host in the upper half of the frame. There is no inflammatory reaction.

Fig. 10-B: The high-power frame shows a projecting spike of necrotic transplant bone in the lower half of the frame united to and being replaced by new living bone from the periosteal new bone.

sional polymorphonuclear cells. This inflammatory tissue prevented repair of the transplant. There were only a few scattered areas of reactive new bone surviving from the early periosteal proliferation of the transplant. There was active destruction of the transplants without replacement. The reactive bone of the host flared out as it approached the transplant-host junction as if it were seeking to encompass the entire inflammatory mass about the transplant.

Forty-Five Days

The union between the periosteal reactive bone of the autogenous preparation had matured. There was replacement of the cartilage at the transplant-host junction by new bone. The reactive bone of the host had become more cortical in character, with remodeling of the unoriented arrangement of its trabecular bars. There was further replacement of the transplant by new living bone, although the outline of the transplant was still clearly visible. It was apparent that the viable cells in the transplant were in areas of newly formed bone and that new osteocytes had not moved into the old vacated lacunae of the original bone.

The homogenous preparations showed progress in the effort of the host at repair. The reactive new bone almost bridged the transplant-host junctions. The transplant was partially destroyed and remained encapsulated in a bed of fibrous tissue from which tongues of fibroblasts and capillaries reached out into the old Haversian canals. There were fewer lymphocytes and giant cells in this tissue.

Of the seven homogenous preparations studied at forty-five days, five evidenced a major inflammatory response with encapsulation of the transplants. One preparation showed no inflammatory response, union across the host and transplant, and destruction of the central portions of the transplant with early replacement. One preparation was

FIG. 11-A

FIG. 11-B

Fig. 11-A: Sixty-day homogenous: The low-power frame shows both cortices of the transplant on either side of the pin tract in the lower half of the frame enmeshed in inflammatory cells and being destroyed without replacement. The reactive new bone of the host, in the upper half of the frame, is flaring out in an attempt to encircle the inflammatory mass about the transplant.

Fig. 11-B: The high-power frame shows a projecting spike of necrotic transplant, enmeshed in inflammatory tissue, undergoing destruction without replacement.

histologically indistinguishable from the autogenous preparations. The entire transplant was surrounded by mature reactive bone; there was bone union at the host-transplant junction, and there was no evidence of inflammation.

Both the parabiotic and presensitized homogenous transplants lay in beds of active inflammatory tissue. The transplants were being destroyed without replacement. The host reactive bone stopped at the transplant-host junction in these preparations, unable to encompass this inflammatory mass.

Sixty Days

The autogenous preparations showed bone union between the reactive bone of the host and the transplant. The transplant had been replaced in increasing amounts, with an absence of any inflammatory reaction. There was little difference in the rate or the amount of replacement of the necrotic cortex of the transplant as compared with the necrotic cortex of the host which had been killed by the original trauma (Figs. 10-A and 10-B).

In the homogenous preparations, the host reactive bone extended out and around the transplant, but within this bridge the transplant remained isolated by a zone of fibrous tissue. The transplant had been partially destroyed and there was no replacement of it. The chronic inflammatory tissue about the transplant was confined to the local area of the transplant and did not extend around the host (Figs. 11-A and 11-B).

Of the seven homogenous preparations studied, five have been described. In one preparation, the transplant was united to the host at the host-transplant junction and was being replaced peripherally. Destruction and replacement of the cortex of the transplant was much less evident than destruction and replacement of the necrotic cortex

FIG. 12-A

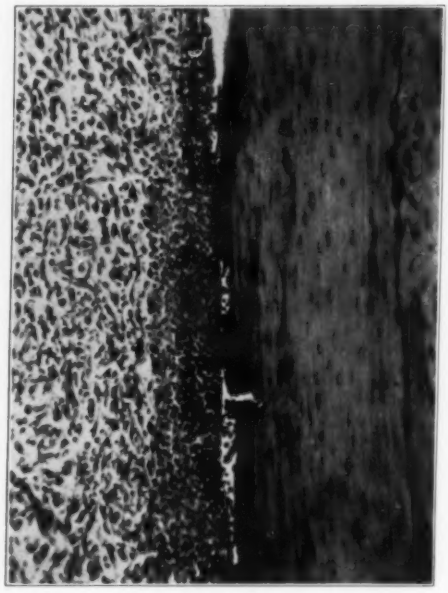

FIG. 12-B

Fig. 12-A: Sixty-day presensitized homogenous: The low-power frame shows the necrotic transplant in the lower half of the frame surrounded by inflammatory tissue, while the periosteal new bone of the host is attempting to bridge this tissue.

Fig. 12-B: The high-power frame shows the necrotic transplant surrounded by inflammatory cells.

of the host. One preparation was the same as the autogenous preparations already described.

The presensitized homogenous and parabiotic preparations showed transplants that lay in capsules of inflammatory tissue. This tissue prevented the host reactive bone from bridging the defect and effectively sealed off the transplant from being replaced or repaired. At this stage, the inflammatory tissue about the transplants was less acute in nature (Figs. 12-A through 13-B).

Seventy-Five Days

The autogenous preparations showed progress in replacement of the transplants. There was bone union between the host and the transplant.

In the homogenous preparations, the transplants remained in their beds of fibrous tissue without varying degrees of reactive bone of the host seeking to encompass them. There was destruction of the transplants without replacement.

Of the five homogenous preparations, three showed sequestration and destruction of the transplants. In two preparations there was absence of encapsulation by chronic inflammatory tissue. There was, however, retardation in the repair of the transplants as compared with the autogenous transplants and as compared with the necrotic cortex of the host in the same preparation.

The presensitized and parabiotic preparations showed the transplants to be partially destroyed. The inflammatory tissue about them was more acute in nature than the tissue about the homogenous transplants. The reactive bone of the host still did not completely encircle this inflammatory tissue.

Ninety Days

The preparations showed a continuation of previous processes. There was further

FIG. 13-A

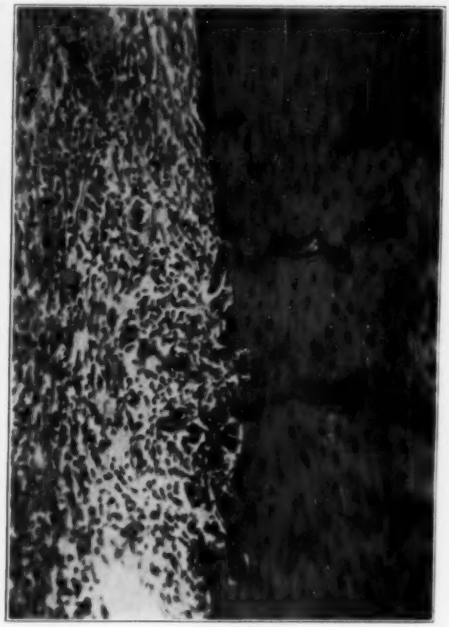

FIG. 13-B

Fig. 13-A: Sixty-day parabiotic: The low-power frame shows the necrotic transplant enmeshed in inflammatory tissue as the periosteal new bone of the host attempts to encircle it.
Fig. 13-B: The high-power frame shows the necrotic transplant surrounded by inflammatory cells.

repair of the autogenous transplants which were now indistinguishable from intact transplants.

There was much diminution in the inflammatory response about the homogenous transplants. The reactive bone of the host flared about the defect and the destruction of the transplant was further advanced.

Of the six homogenous preparations studied, four have been described. Two preparations showed no inflammatory response about the transplants. One was indistinguishable from the autogenous preparations, and one, although having no inflammatory reaction, showed a decided lag in repair.

The parabiotic and presensitized preparations showed fragmented, sequestrated transplants. The inflammatory response was less intense than that seen in earlier preparations. There was slight progress of the reactive bone of the host in bridging the defect.

One Hundred and Five Days

Little change had taken place. Replacement of the remaining necrotic cortex of the autogenous transplants had advanced, however.

The remains of the homogenous transplants were in beds of dense fibrous tissue. The incomplete host repair bridges had developed into more mature bone.

Of the five homogenous preparations, three showed the fragmented transplants sequestrated from the incomplete host repair bridges. Two showed no sequestration of the transplant by dense fibrous tissue. One of these two preparations showed partial destruction and replacement of the transplant which was more advanced in the region of the host-transplant junction than it was centrally. The other preparation resembled an autogenous transplant.

The fragmented, disappearing, parabiotic, and presensitized homogenous trans-

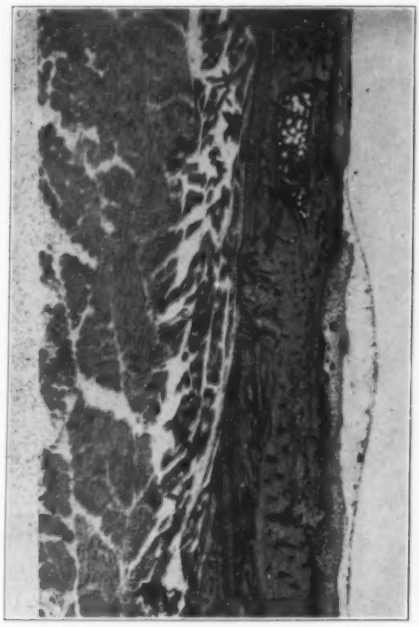

FIG. 14-A

FIG. 14-B

Fig. 14-A: One-hundred-twenty-day autogenous: The low-power frame shows the transplant in the lower half, with its remodeled cortical periosteal new bone indistinguishably united to the host periosteal new bone in the upper half of the frame.

Fig. 14-B: The high-power frame shows the interior of the transplant with an old Haversian canal that has been excavated and is now filled with new bone, and the attendant capillary in the lower third of the frame. Along the upper border of the frame is a seam of new living bone laid down along the free margin. The remaining necrotic bone is awaiting this destruction and replacement.

plants were still situated in inflammatory beds which thwarted the efforts of the host at repair.

One Hundred and Twenty Days

Four months after transplantation the experiments were terminated. The autogenous transplants had become united to the host and were replaced to a large extent (Figs. 14-A and 14-B).

The homogenous transplants were not entirely destroyed and the remaining fragments lay in beds of dense fibrous tissue. The reactive bone of the host incompletely bridged the defect, and bone union about the transplant had not taken place (Figs. 15-A and 15-B).

Of the seven homogenous preparations, five were as described. Two preparations were well united and partially replaced.

There was destruction and fragmentation of the presensitized homogenous and parabiotic transplants, with chronic inflammatory tissue still surrounding them. In areas where portions of the transplants had been completely destroyed, the inflammatory cells were replaced by dense fibrous tissue. At this stage, the reactive bone of the host had not yet been able to bridge the defect and bring about union (Figs. 16-A through 17-B).

DISCUSSION

This report describes the response of the host to large bone transplants of the various types studied at stated time intervals. There is no precise end point in histological interpretation, nor is there merit in attempting to quantitate these findings in terms of curves

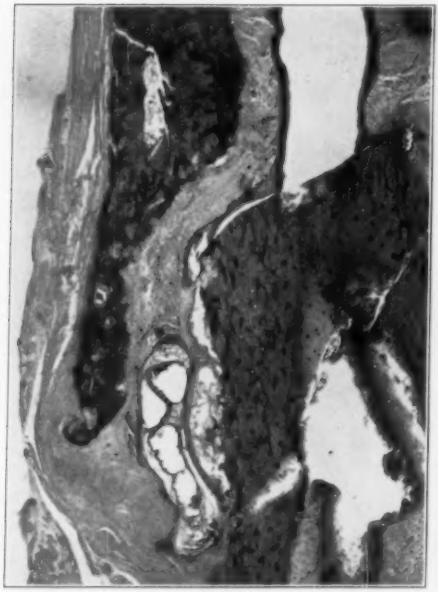

FIG. 15-A

FIG. 15-B

Fig. 15-A: One-hundred-twenty-day homogenous: The low-power frame shows the necrotic transplant in the lower half of the frame surrounded by dense fibrous tissue, and the encircling periosteal new bone of the host attempting to bridge the transplant.

Fig. 15-B: The high-power frame shows the necrotic transplant being destroyed and surrounded by mature fibrous tissue and chronically inflamed cells.

and graphs. The results represent only the broad, easily recognizable constant points of differentiation, and conclusions are based on these points (Chart I).

Until the fifteenth day of the experiment, there was no difference in the response of the host animals to the transplants in the various preparations. The surviving elements of the various types of transplants showed no significant difference in the rate or in the amount of proliferation. It is possible that this period may represent the immunologically latent period in which antibodies, stimulated by the transplant, are being produced. This lag corresponds very closely to the reported time interval for the production of antibodies in the rat [15].

From the fifteenth day on, there were marked differences in the various types of preparations which are illustrated by the photomicrographs.

Only in the autogenous preparations did the proliferations of the transplants consistently survive and aid in the process of repair. Thirty-four of the homogenous transplants showed a major inflammatory host response which obliterated the periosteal proliferations and prevented the repair or replacement of the transplants. Eleven of the homogenous transplants evoked a minor inflammatory response which did not prevent the periosteal reactive bone of the host from crossing the transplant-host junction and subsequently repairing and replacing the transplant (Figs. 18-A and 18-B). Seven of the homogenous transplants appeared in all ways as autogenous transplants (Figs. 19-A and 19-B).

The degree of inflammatory response between partners in the paired animals was constant. In no instance was there a major inflammatory response in one partner and minor or absent inflammatory response in the other partner. This emphasizes the validity of histological interpretation in antigenically similar animals. The incidence of major inflammatory responses to the homogenous transplants paralleled the incidence of fatal intoxication in randomly selected rats subjected to parabiosis. The incidence of absent

FIG. 16-A

FIG. 16-B

Fig. 16-A: One-hundred-twenty-day presensitized homogenous: The low-power frame shows the partially destroyed necrotic transplant in the lower half of the frame surrounded by fibrous tissue, and the remodeled periosteal new bone of the host in the upper half being halted by this tissue.

Fig. 16-B: The high-power frame shows the transplant surrounded by fibrous tissue and inflammatory cells with destruction of the transplant.

FIG. 17-A

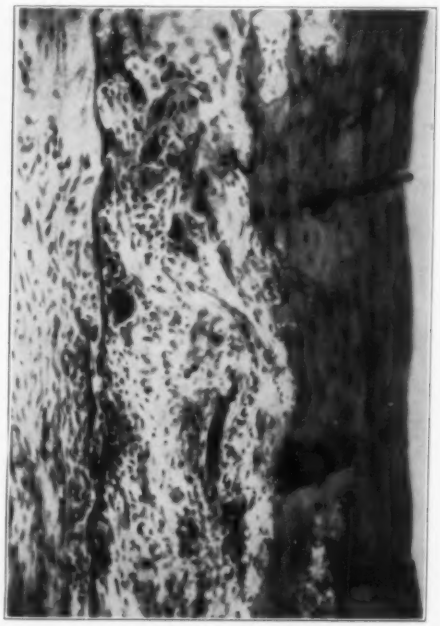

FIG. 17-B

Fig. 17-A: One-hundred-twenty-day parabiotic: The low-power frame shows the partially destroyed transplant enmeshed in fibrous tissue in the lower half of the frame, and the large amount of periosteal new bone attempting to encircle and by-pass the transplant.

Fig. 17-B: The high-power frame shows the necrotic transplant surrounded by chronically inflamed tissue being destroyed without replacement.

FIG. 18-A

FIG. 18-B

Fig. 18-A: Forty-five-day homogenous: In the low-power frame there is mature periosteal new bone from the host in the upper half of the frame filling the host-transplant junction and crossing this junction to unite with the necrotic graft in the lower half of the frame.

Fig. 18-B: The high-power frame shows the necrotic transplant with new bone from the host in the lower portion of the frame. The more central portion of the frame shows an absence of the gross inflammatory changes seen in the majority of instances about a large homogenous transplant. There is no evidence of survival of transplant periosteum.

or minor inflammatory responses to homogenous transplants paralleled the incidence of survival in randomly selected rats subjected to parabiosis. The consistency of these observations in the experiment may explain the conflicting reports as to the fate of homogenous-bone transplants. In animals of low-order antigenic complexity there will be a predictable number of animals that are immunologically compatible. Tissue transplants exchanged between these animals will not provoke major inflammatory response. This percentage of acceptable homogenous transplants would seem to diminish as the species become more antigenically complex.

In these experiments, the inflammatory response to both types of presensitized homogenous transplants was constant. The response to the host animals to the "second-set" presensitized homogenous transplants fulfilled the definition of a delayed-sensitivity or Arthus-like reaction. The animals had been exposed previously to the antigen by the initial homogenous transplant. Sufficient time had elapsed for antibodies to form in response to the antigen, and the inflammatory response to the second introduction of the antigen was much more intense than the first, and was confined to the site of antigen localization. When these observations were duplicated in parabiotic preparations, the suggestion was advanced that this reaction was due in some measure to a systemically formed, circulating antibody. This must be confirmed by the identification of specific precipitating antibodies in other species harboring antibodies which may be detected by presently available methods.

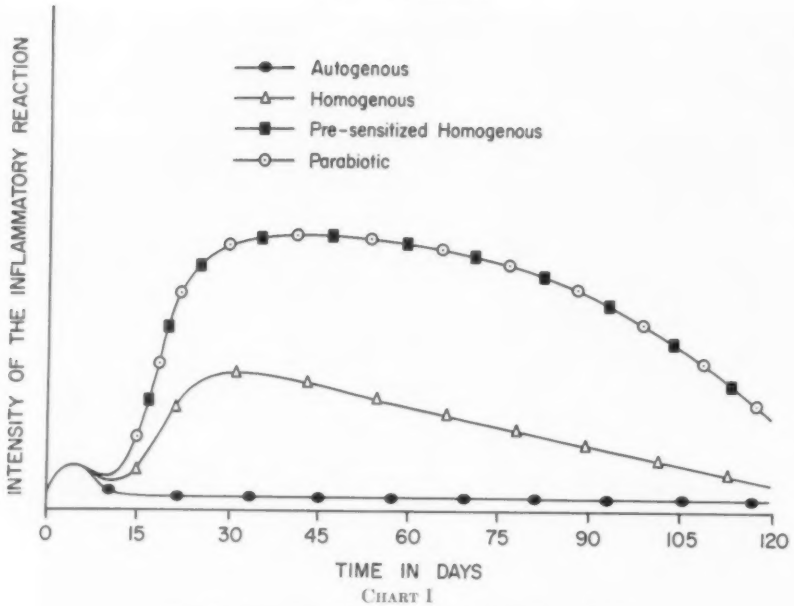

CHART I

Graphic summary of host response to bone transplant.

These results are in agreement with and corroborate in close detail the results obtained by other investigators working with homogenous-skin transplants. The persistence of the inflammatory response to bone transplants beyond that to skin transplants may be due to the longer period required for destruction of the antigen-bearing transplant. This suggests that the antigen is, in part, confined within the bone and is not entirely obliterated until all of the necrotic bone has been destroyed.

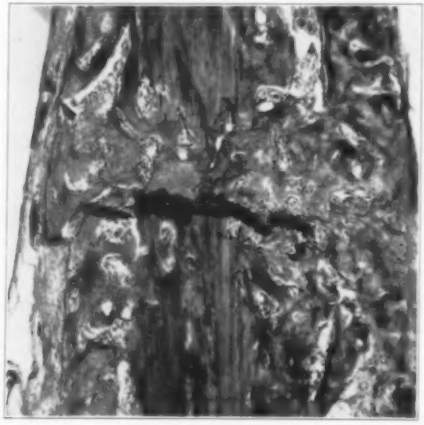

FIG. 19-A

FIG. 19-B

Fig. 19-A: Thirty-day homogenous: The low-power frame shows the host cortex in the upper half of the frame surrounded by periosteal and endosteal new bone, and the transplant in the lower half of the frame is similarly encased in new bone. There is bone union between the new bone of the host and the new bone of the transplant.

Fig. 19-B: The high-power frame shows the periosteal new bone about the central portion of the transplant united to and replacing the necrotic cortex. There is no inflammatory reaction.

The partial survival and utilization of those homogenous-bone transplants which did not provoke an inflammatory response is of great interest. It would suggest that "de-antigenizing" a homogenous transplant, or altering the immunological mechanism of inflammation by "de-sensitizing" the host, would enable large homogenous transplants to produce results which would compare favorably with autogenous transplants.

SUMMARY

1. There is a significant inflammatory response to large homogenous-bone transplants in rats. The incidence of this inflammatory response corresponds to the predictable incidence in randomly selected animals.

2. The inflammatory response is intensified in presensitized homogenous preparations in rats, which may represent a delayed-sensitivity or Arthus-like reaction.

3. Evidence is presented, by means of parabiosis, to show that this reaction may be due to a systemically formed circulating antibody. Confirmatory evidence by immunological methods is needed.

4. This histological demonstration of a delayed sensitivity or Arthus-like reaction, using bone transplants as the antigen and showing indirectly the presence of the circulating antibody, suggests that the rejection of homogenous bone transplants in rats may be due to an antigen-antibody reaction indicating a state of active acquired immunity.

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Bipedal Rats and Mice

Laboratory Animals for Orthopaedic Research*†

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Orthopaedic research, related to diseases and disorders of posture, calls for a suitable laboratory animal. Gravity should act on such an animal somewhat as it does on man. While much is known about the origin and development of human posture [7, 10], a great deal remains to be learned. Scoliosis, degenerated intervertebral discs, osteo-arthritis, changes about the hip and knee joints, foot disorders, and many other conditions could be investigated with greater validity if laboratory animals, inexpensive and comparable, were available for experimental purposes.

METHOD OF SELECTION

Many species came to mind—dogs [13], cats, goats, pigs, and cattle, and occasionally-available primates. Their life histories and their potential adaptations as bipeds were examined, but all were rejected for practical reasons.

Anthropoids—monkeys, chimpanzees, and gorillas—are scarce and expensive. They are actually quadrupeds showing only occasional attempts at bipedalism. Some are being used today in special laboratories, but they are not available for typical investigators.

The kangaroo was rejected because it is a hopper. Its stance is not plantigrade (walking on heels) [12]. Other smaller marsupials, such as the opossum, are being studied. Dogs, cats, and pigs have never demonstrated any trend toward bipedalism as means of locomotor progression. Such a trend seemed important in selecting a suitable animal.

Rodents were chosen because of many traits, especially a preference for erect sitting and walking [5]. These small animals are easily handled in the laboratory, recover readily from surgical operations, strongly resist trauma and infection, breed rapidly, and produce large litters. The white rat, as used by Colton [2] in his studies of heredity, has responded satisfactorily. Likewise DBA strains of mice have proved their laboratory adaptability. In the animal classification, rodents are listed before primates, the great division to which man belongs. Shrews have been shuffled back and forth between the *Rodentia* and the *Primates* ever since Linnaeus first classified them in 1758. Some scientists still question in which general classification the shrew should be placed. They are unmistakably rodent-like; yet the tree shrew is placed foremost in the division *Primates*.

EXPERIMENTAL PRODUCTION

Wistar rats and DBA mice were chosen for the experimental production of bipedal animals. Newborn rats, between eighteen and thirty-six hours old, and DBA mice, sixty to seventy-two hours old, were operated upon under hibernation anaesthesia. They were lifted from the nest and placed on a tray of ice cubes for twelve to fifteen minutes, or for ten minutes in a deep freeze. The animals' two forelegs were tied with cotton transfixation ligatures at the mid-humeral level, and the tail at its base. Then the upper extremities above the elbow and the tail were cut off with scissors. No bleeding followed if the ligatures were secure.

* Read at the Annual Meeting of the Orthopaedic Research Society, Chicago, Illinois, January 28, 1956.
† Read at the Annual Meeting of the American Association of Physical Anthropologists, Chicago, Illinois, April 10, 1956.

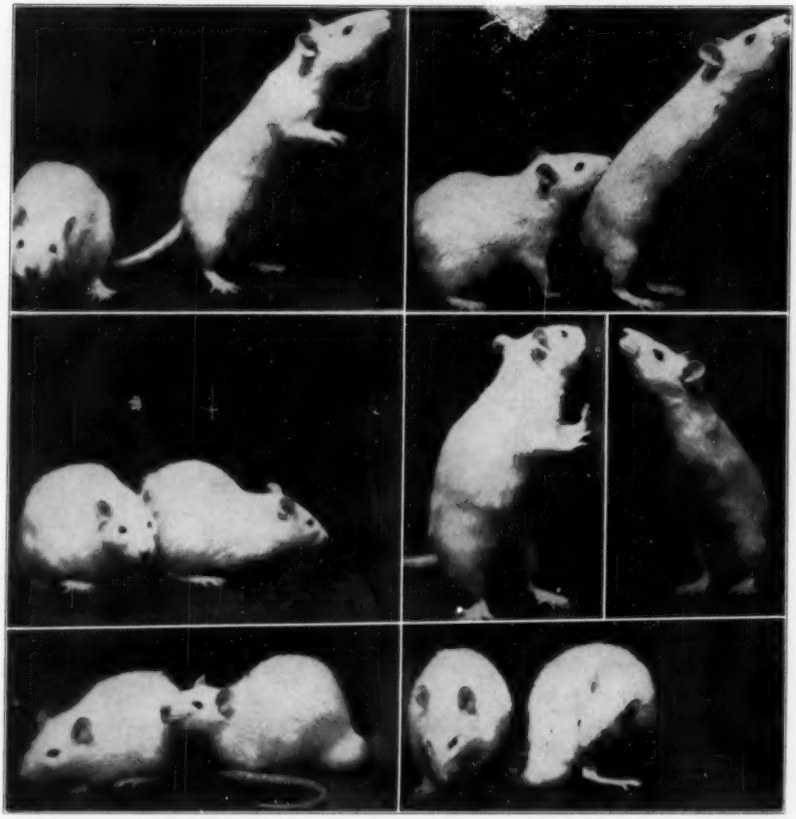

FIG. 1

Wistar white albino rats 150 days old, litter mates; one was converted to bipedalism by surgical amputation of the forelegs above the elbows; the other was not operated upon.

The animals were revived in a bacteriological incubator at 37 degrees centigrade until they were active. The entire litter, including controls unoperated upon, were returned to the nest at the same time. Care, feeding, and frequent cleaning of cages were necessary for optimal survival. During the first few days, cannibalism was high among both species, particularly among the mice. Cannabalistic mothers were not bred again. The young were weaned at twenty-one to twenty-eight days. From then on, they were fed a standard laboratory diet.

Breeding Data [5]

White rats, Wistar albino strains, have a gestation period of twenty-one to twenty-three days. They are fertile at sixty to ninety days and remain so until 300 days of age. Their menopause occurs at fifteen to eighteen months; their life span is about thirty-six months, corresponding to ninety years in man. The mother eats the placenta at birth, which is thought to furnish a growth-promoting substance for her milk. This characteristic may account for the cannibalism which sometimes impels the mother to eat her entire litter during their first few days of life. Brother-sister matings do not produce undesirable traits in such pure strains. Size, color, and other characteristics breed true.

Young rats and mice begin to nurse during the first twelve hours after birth. They will try to find their mother in seven or eight days, and they open their eyes in fourteen

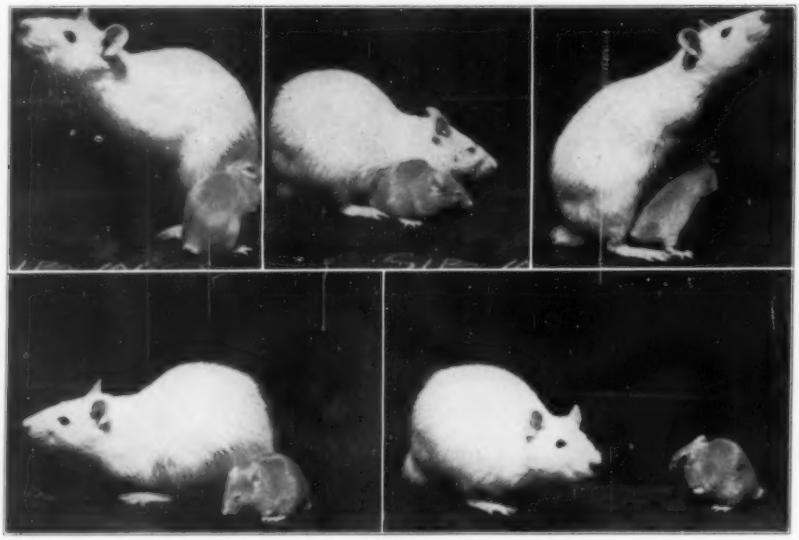

FIG. 2

Bipedal rat and DBA mouse postures. These were comparable, but the animals' gaits varied. There was frequent reversion to hopping in the mouse; an alternate left-right gait was noted in the rat.

to seventeen days. Their ears open earlier. Such slow development requires a nest for control so that the nursing mother can cover the mouths of her young with minimal searching on their part. The rats and mice operated upon are handicapped relatively

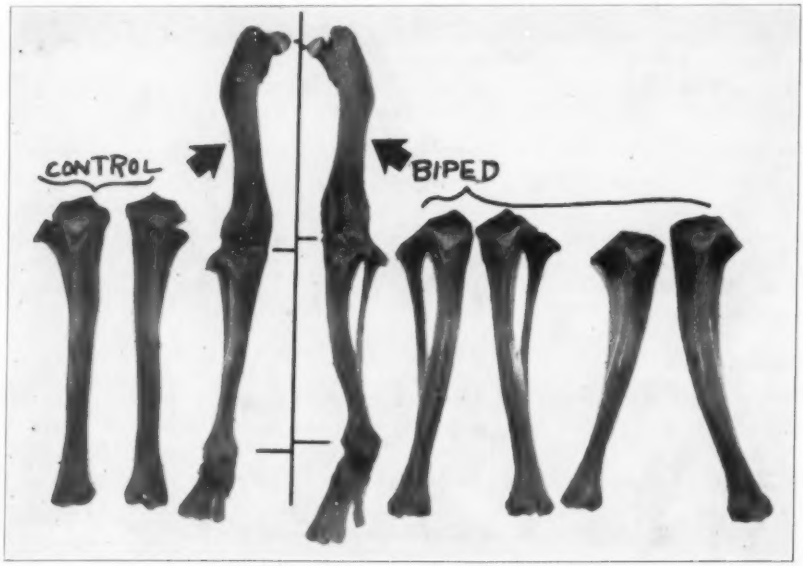

FIG. 3

Anterior views of typical femora and tibiae showing bowing in bipedal elements, resulting in a knock-knee stance, larger tibiae, longer femora. Due to parallax of photography, the biped femur illustrated appears shorter than it actually is. Biped ankles are broader.

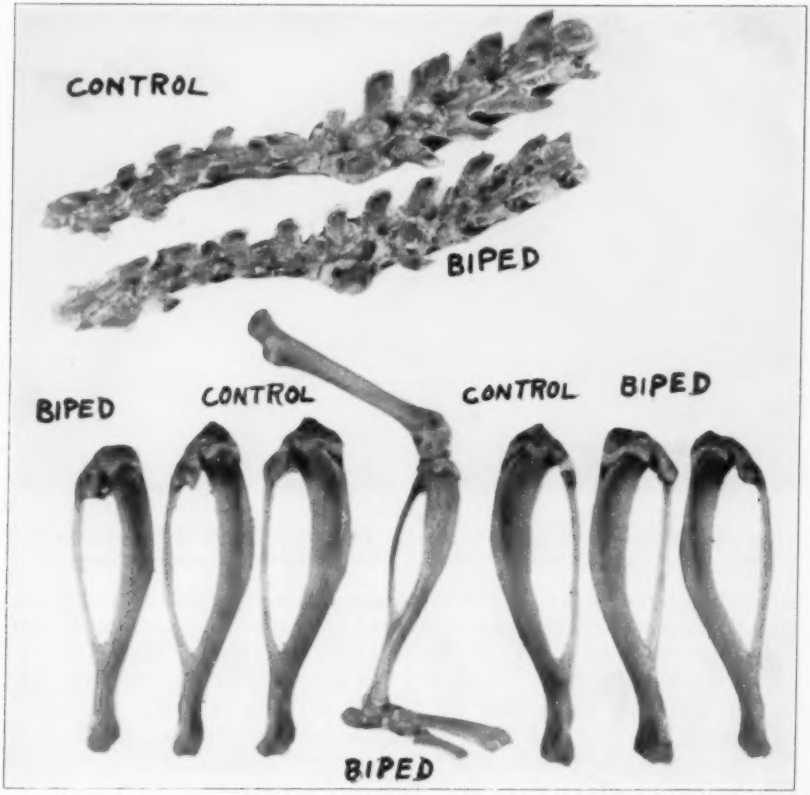

FIG. 4

Lateral views of the bones of litter mates. Note the greater cephalad angulation of spinous processes of vertebrae and an absence of alteration of the normal anterior bowing of the tibiae. This element was unchanged but the thickness was enhanced. The calcaneus was a trifle longer in the bipeds; the metatarsals were unchanged.

little. Nevertheless, they are decelerated in growth rate and never reach the size of their control litter mates which were not operated upon.

Exercise and Learning

Long, high cages were used to encourage bipedalism, which was rapidly learned. Raised with control litter mates, bipedal animals soon became their equals in activity. Since rodents are nocturnal in their activity habits, they were observed best in the twilight, with only dim lights nearby. During these hours the bipedals spent nearly all of their time walking erect. The absence of forelegs and tails offered no special obstacle, and even when resting they squatted with chest and abdomen off the floor. Thus they were compelled to bear full weight on their hind limbs. Adaptations followed this demand, and true bipedalism became a habit, accompanied by alterations in bones, joints, muscles, and coordination.

Adaptation Behavior

Many litters were observed for eighteen months. Although some animals excelled in their acquired method of movement, all learned rapidly. The bipedal rats and mice walked nearly erect, spreading their feet and toes apart. Their spraddled gait, with heels flat, was

FIG. 5

Roentgenographic studies. Note the voluntary, therefore functional, lateral scoliosis which is always present. Bipedal rats demonstrated a dorsal kyphosis and no lumbar lordosis.

striking. Their bodies were flexed forward in the mid-thoracic region but readily straightened when the animals stretched for food placed high or when they sniffed their surroundings, a characteristic behavior. All the animals used short strides, placing each foot alternately before the other. Mice preferred to hop with both feet together. The rats had a penguin-like waddle. Of course, they had no tails to aid in balancing. No difficulties in drinking, feeding, breeding, and defending themselves were observed. Occasionally a rat would rest its chest on the floor to doze. No alteration was observed in their dispositions; some were biters and some were not, as was true among their normal litter mates.

PREPARING SPECIMENS

At various intervals, entire litters were sacrificed by dropping them into a large vessel containing a few centimeters of chloroform. The animals were easily skinned; their skeletal parts were cleaned, measured, and stored in the deep freeze.

Whole specimens were prepared by soaking them in polyethylene glycol 600 with 10 per cent formaldehyde. After draining and drying they were ready for preservation in a clear plastic block.

STRUCTURAL ADAPTATIONS

Measurements of bones and other structures were systematically recorded. Each animal's growth rate was computed by comparing individual body parts with the cranium. For example, the length of the femur was divided by the length of the cranium and multiplied by 100. The result was used as an index of growth at a given age when the animal was sacrificed and cleaned. A statistical analysis of these body parts will be published in a later paper. Other unit indices were obtained in the same manner.

As many diameters, lengths, and breadths as seemed pertinent were measured with calipers and recorded. Only correlations and comparisons were significant, and these indicated that many of the animals showed a trend toward bipedalism of a character similar to man.

Knock-knee occurred markedly in the young animals. This condition was produced by bending of the proximal portion of the tibia and the fibula. Since rickets is not possible in the rat, the knock knees were significant. Ankles and feet were wider apart in the bipedal

animals than in the controls, and the ankle mortise was broader than in the normal animals. The femur was proportionately longer in relation to the tibia in the rats operated upon. Hip and knee joints were relatively unchanged. The pelvis may have been slightly changed, but if so, the change was not discernible. The spinal column, vertebrae, and sacrum seemed unaltered except for the spinous processes. These structures tended to angulate toward the head. In the controls, these projections pointed more toward the tail. A dorsal kyphosis appeared to be quite common, but no scoliosis and no lumbar lordosis were observed. Perhaps such a dorsal kyphosis in a former quadruped is the equivalent of a lateral scoliosis in bipedal man. The calcaneus was slightly longer. The metatarsals remained unchanged in length but were spread farther apart. These variations correlated well with those reported by Colton [2].

OTHER PROCEDURES

Motion pictures were made to demonstrate the types of foot fall and manner of locomotion of bipedal rats and the controls. Because intense light depresses rodent activity, infrared motion-picture techniques are recommended.

Roentgenographic studies, combined with rapid-exposure photography, indicated the feasibility of such procedures for research purposes.

Financial accounting showed that fifteen dollars represented the total cost of production and maintenance of an animal throughout its lifetime.

DISCUSSION

Apart from Colton's efforts, similar work has been done by Knickmeyer, Fuld, and notably Slijper; Slijper raised a goat which had been born without forelegs. This animal was carefully studied and its adaptations were accurately recorded to indicate alterations of anatomical parts. These alterations consisted in a change in the shape of the thorax, proportional differences in the femur and tibia, as well as a lumbar lordosis and cephalad angulation of the spinous processes. Similar changes are regarded by all authors as manifestations of the effects of a shift in the animal's center of gravity. Pratt studied the behavior of erect-walking bipedal rats without recording their anatomical changes. His rats persisted in face-washing with their "phantom limbs", reputed to be one of their habitual reflex activities. His rats, like our animals, could occasionally jump twelve to fourteen inches out of a pail. Pratt, likewise, reported a dorsal kyphotic stance but made little of it. We were impressed by the limitations of alterations which our animals demonstrated. Some investigators believe that these indicate an experimental directive as expressed by Simpson's quantum evolution theory [4]. Perhaps so, but since no mutations were produced, no such conclusion can be drawn. All biped parents had quadruped offspring. Colton [3] carried on his study for many generations and reported the same results.

However, there are pertinent aspects of great value in these bipedal adaptations. Rats and mice may be so altered that they will show anatomical and behavioral changes in accordance with Wolff's law and the law of squares and cubes. Every orthopaedist knows the former. The latter was expressed by Bergman as changes of the proportions of organs with surface areas such as skin, intestines, lungs, and cortex of bones. These increase as their squares while the bulk of the body is increasing as its cube. Both laws seem to be validated by our animals.

Finally, realistic bipedal laboratory animals were produced with comparative ease and at low cost. Research workers in orthopaedics may use these animals with greater validity in their results than previously, when investigating affections influenced by gravity.

NOTE: This experiment in animal posture was originally suggested by Prof. S. L. Washburn, Department of Anthropology, University of Chicago, who encouraged the senior author to investigate these interesting animals.

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Some Aspects of the Ultrastructure of Bone

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In the animal kingdom, many different inorganic salts and organic compounds form the hard tissues, but the vertebrates are unique in utilizing the properties of the calcium phosphate-collagen system in the construction of their skeletons. The ultrastructure of this system has been studied extensively during the last decade by means of physical methods, and new insight has been gained into the role of the skeleton as a physiological system of the body. Since the principal constituents of bone—that is, inorganic salt and the fibrous protein, collagen—have a crystalline structure, investigations by polarized light and x-ray diffraction have been most profitable. Study of bone by electron microscopy has also yielded contributions to the understanding of its finer structure, although technical difficulties have been encountered in sectioning because of the hardness of this material.

The nature of the inorganic fraction remained obscure when examined solely by chemical analysis. It had been shown repeatedly that calcium, phosphate, and carbonate are the main components of bone salt, but no chemical formula had been found which could completely account for its composition. By physical methods, however, it was possible to demonstrate that the bone salt, as well as the mineral component of tooth enamel, has a crystalline structure similar to that of certain basic calcium phosphates called apatites.

These studies also revealed that the crystallites of calcium phosphate are extremely small, measuring about one hundred-thousandth of a millimeter.

Several investigations have been carried out to determine the shape and size of the apatite crystallites, but the findings are not yet in complete agreement. From the line-broadening effect in x-ray diffraction patterns it has been deduced that the crystallites in bone or in dentin are elongated, and that their length is about 200 to 290 Angström units[1, 12, 14]. (One Angström unit = 10^{-8} centimeter.) Low-angle particle scattering of x-rays has also shown that the apatite crystallites from a variety of vertebrate species are probably rod shaped and are fairly uniform in size; the dimensions are calculated to be 200 to 220 by 65 to 75 Angström units. These findings are in good agreement with the line-broadening data [2, 4]. From the study of electron micrographs of sectioned bone tissue, however, it appears that the apatite of bone forms tabular crystallites which, in adult bone, appear to have the dimensions of 400 by 200 to 300 by 25 to 50 Angström units; whereas the crystallites in infant and senile bone appear to have lengths of less than 100 and more than 1,000 Angström units, respectively [7, 8].

Although there is a discrepancy between the sizes of the crystallites when they are calculated from x-ray data and from observations in the electron microscope, the results agree well when the surface area is calculated from these dimensions. Thus, one gram of bone salt possesses about 130 square meters of surface area which is capable of binding and of adsorbing large amounts of different ions. The carbonate found in the bone salt (amounting to 3 to 6 per cent) does not seem to occur in crystalline form as calcium carbonate [1, 11], and for this reason the theory has been proposed that the carbonate substitutes for phosphate groups in the apatite structure [6]. From the point of view of surface phenomena, however, it is likely that the carbonate is fixed to the surface of the extremely small crystallites [1, 5].

Investigations with polarized light [9] and x-ray diffraction [1, 2, 13] have shown that the apatite crystallites are oriented with their long dimension parallel to the collagen fibers. This appears not to be due solely to mechanical factors but rather to reflect a chemical relation between the collagen structure and the apatite crystallites. Electron micrographs of bone show that the crystallites are attached to the collagen fibers in a regular manner with reference to the crossbandings of the collagen [8, 10]. From x-ray crystallographic data it has been suggested that three apatite crystallites, 210 to 220 Angström units long, fill up the 640 Angström unit interband repeating period along the collagen fibers [2, 4]. It is possible that certain regularly spaced groups along the polypeptide chains of collagen act as crystallization centers for the apatite and that these groups determine the spatial direction of the first established calcium phosphate molecules in calcifying structures.

The calcium phosphate collagen system not only fulfills the mechanical demands of hardness, strength, and elasticity required by the skeleton in its supporting role, but also is functional in maintaining the ionic balance of the body fluids. Because of the great surface area of the crystallites in the skeleton, and because of their ability to bind and adsorb ions, especially those having a physicochemical relationship with the ions in the apatite structure, the skeleton acts as an important ion-exchanger. It has long been known that radium, lead, and strontium show a strong affinity for the skeleton. By means of microradiography and autoradiography it has been found that when certain radioisotopes are administered to young animals, the concentration of the isotopes is greatest in growing or newly formed mineralized tissues [3]. This phenomenon may depend on the existence of a looser packing of the crystallites in regions of growth, making available a larger surface area for exchange and adsorption. This capacity of the skeleton to incorporate foreign ions in its structure is of great interest in the atomic age since many of the most common fission products are bone-seeking in their behavior. Thus, for example, the long-lived strontium isotope (Sr^{90}), once incorporated in the skeleton, may remain for a lifetime and, depending on its concentration, may result ultimately in damage to bone

marrow or in a malignant transformation of the bone tissue. A better understanding of the ultrastructure of calcified tissues may aid in the development of a solution to the problem of eliminating bone-seeking radio-isotopes from the body.

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The Calcar Femorale and the Femoral Neck

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Recent articles on the treatment of femoral neck and trochanteric fractures by means of pins, plates, or prostheses contain many references to the calcar femorale. This structure was described almost 100 years ago, but precise knowledge concerning its location and nature was later lost, and today many clinicians are still confused on these points.

In 1874, Merkel gave a detailed description of the calcar femorale, which he called "der Schenkelsporn" or femoral spur. He pointed out that Wolff had already mentioned it in 1869, describing it as "the compact tissue on which the trochanter minor rests", and that even earlier (1859), it had been illustrated, without comment, in *Anatomica Topographica* by Pirogoff of St. Petersburg. Bigelow, in 1875, discussed the pathological nature of trochanteric fractures and mentioned the influence of the presence of the femoral spur on the pattern of the bone fragments.

In many current texts anteroposterior roentgenograms are labeled incorrectly to show the calcar femorale as the thickened and condensed cortical buttress of bone at the junction of the neck and medial portion of the femoral shaft (Fig. 1). The bone in this region undoubtedly has the thickest and densest cortex in the femur, a fact which is readily appreciated during decalcification of the femur since it is in this area that the last remnants of calcium are retained.

FIG. 1

FIG. 2

Fig. 1: Roentgenogram of a segment of the proximal end of the femur showing Ward's triangle in the center of the neck. The arrow points to the pressure buttress; this is not the calcar femorale.

Fig. 2: The calcar femorale in a left femur. *F*, calcar femorale; *L T*, lesser trochanter.

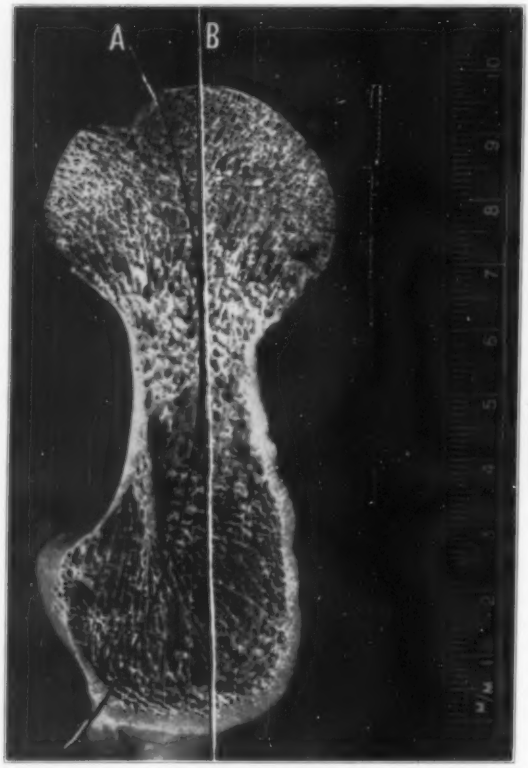

FIG. 3

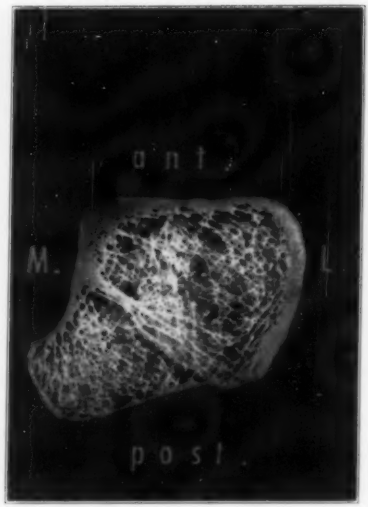

FIG. 4

Fig. 3: A longitudinal section through the lower portion of the neck of a right femur. The calcar and the thin-walled intertrochanteric crest are visible. *A*, curved axis; *B*, straight axis.

Fig. 4: Transverse section of a right femur at the level of the lesser trochanter. The calcar extends into the cancellous bone from the medial portion of the cortex.

THE CALCAR FEMORALE

The calcar femorale is a dense vertical plate of bone within the femur (Fig. 2). It originates in the posteromedial portion of the femoral shaft, under the lesser trochanter, and radiates laterally through the cancellous tissue toward the greater trochanter (Figs. 3 and 4). Superiorly the calcar femorale fuses firmly with the cortex of the posterior aspect of the femoral neck; distally it extends for about two inches anterior to the lesser trochanter and then fuses into the posteromedial aspect of the diaphysis (Fig. 5). The calcar reaches its maximum length and thickness at the level of the upper margin of the lesser trochanter, diminishing progressively in size after that point. Examination of a transverse section shows that the calcar femorale points laterally and backward from the medial side of the shaft toward the gluteal tuberosity (Fig. 4).

All anatomical structures display minor variations in size; the calcar femorale is no exception. If the end-on view shows the linear condensation of bone lying anterior to the lesser trochanter, blending with the cortex of the upper posterior portion of the neck, then roentgenographically the calcar can be visualized only by a lateral view (or by a roentgenogram made with the patient in the so-called frog-leg position) (Fig. 6).

In the region in which the calcar femorale is joined to the medial side of the diaphysis, the cortex is distinctly thickened. This thickening continues to a lesser extent along the front of the greater trochanter and then again increases on the lateral aspect, ending abruptly at the gluteal tuberosity (Figs. 3 and 4).

In a sloping horizontal section which bisects the femoral head and neck, the axis of the femoral neck is represented by a curved line with a forward convexity (Fig. 3, *A*).

FIG. 5

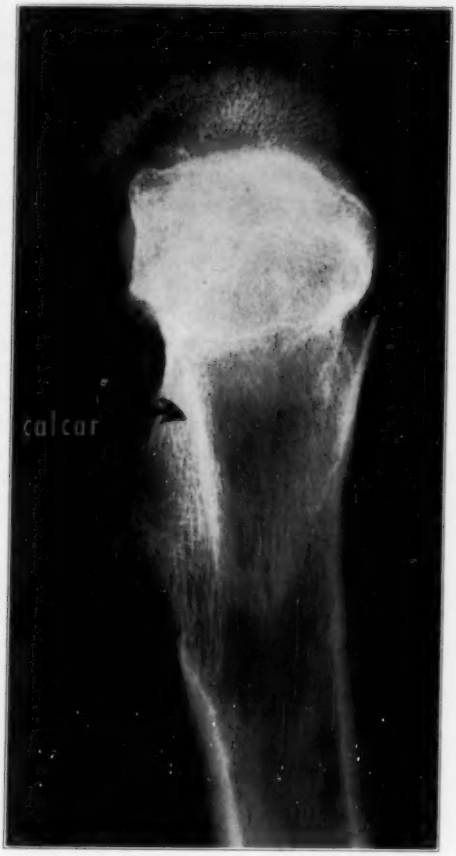

FIG. 6

Fig. 5: Lateral view of a right femur showing the position of the calcar femorale (the greater trochanter has been removed).

Fig. 6: Lateral roentgenogram of the upper end of the femur; the calcar projects downward from the back of the neck.

If the backward projection of the thin-walled traction epiphysis of the intertrochanteric crest and lesser trochanter is ignored, the axis of the neck appears as a straight line which terminates laterally midway between the calcar femorale and the anterior surface of the greater trochanter, that is, along the axis of the original shaft (Fig. 3, *B*). This curvature of the axis of the femoral neck, combined with the projection of the intertrochanteric crest, gives the lateral rotator muscles a definite mechanical advantage in movements of the hip joint (Fig. 7). Fick calculated that the moment of the lateral rotators is three times more powerful than that of the medial rotatory group.

In the femur the angle of torsion is the angle formed by the axis of the knee joint, which is parallel to the posterior surface of the condyles, and the axis of the femoral neck [7]. The average measurement for this angle is 14 degrees of anteversion; however, as Mikulicz indicated in a detailed study, the angle varies from 37 degrees anterior (anteversion) to 25 degrees posterior, a total range of 62 degrees. This divergence indicates the futility of using an average figure in attempting to estimate the direction of the femoral neck on the basis of the position of the flexed leg.

On the medial surface of the femur, anterior to the lesser trochanter, there is often

a faint vertical ridge passing upward toward the posterior surface of the neck. This ridge is produced by the attachment of the pubofemoral ligament. Its position coincidently corresponds to the position of the underlying calcar femorale.

ONTOGENY

In a newborn human baby the shaft of the femur is ossified, but the femoral head, neck, and the intertrochanteric crest, as well as the greater and lesser trochanters, are represented by one continuous mass of epiphyseal cartilage which can be separated intact from the bony diaphysis. This pattern is found in all other mammals and persists for a variable period after birth. No calcar is visible in the infant femur, but by the time the child is three years old, bony lamellae are present on the deep surface of the cartilaginous lesser trochanter. These lamellae become more obvious at puberty, when the intertrochanteric crest and lesser trochanter have grown away from the original oval diaphysis. The calcar femorale reaches its maximum size and density about the twenty-fifth year. In the aged patient thinning and decalcification of the trabecular bone and its replacement by yellow marrow are typically found in Ward's triangle at the base of the femoral neck and also in the calcar femorale. I examined the femora of 110 persons, aged seventy-five years or more. In 60 per cent of these femora Ward's triangle contained no trabecular bone but was entirely occupied by yellow marrow.

The angle between the shaft and neck of the femur ranges from 110 degrees to 145 degrees. It is commonly smaller in women than in men and decreases during the period of active growth. In the absence of pathological changes, no evidence of reduction of this angle occurs even in aged patients, a finding which has also been reported by Bell and Humphry.

During infancy, the epiphyseal plate of the upper end of the femoral neck lies practically in the horizontal plane. During growth, however, it rotates into a more vertical position, as Walmsley has emphasized. This alteration is brought about by more active growth at the upper margin of the juxta-epiphyseal line and by reduction of the angle between the shaft and neck of the femur. In this period, the upper femoral epiphyseal plate also tilts into a more backward position and the intertrochanteric crest becomes more prominent posteriorly (Figs. 3 and 7).

DISCUSSION

The medial and backward deviation of the neck of the femur produces maximum pressure stresses on the inner-posterior surface of the upper quarter of the shaft. The calcar femorale reinforces the weak, angulated bone in this region and helps preserve the continuity of the cylindrical femoral shaft into the neck despite the backward projection of the lesser trochanter and intertrochanteric crest (Fig. 5). On the lateral aspect the epiphyseal line of the greater trochanter, which corresponds to the cortex of the original shaft, is preserved as dense lamellae, with slight modifications in accordance with Wolff's law.

All long bones have characteristic curves, and such curves may be seen in the inner architecture of the upper end of the femur. It is because of these curves that the resistant osseous tissue possesses elasticity, for sudden shocks are distributed on the arch principle along the whole length of each arc [3].

The presence of the calcar femorale and the direction of the subcapital epiphyseal plate influence the characteristics of some of the pathological lesions which occur in the upper portion of the femoral shaft.

The mechanism of the trochanteric fracture has been well described by Evans and associates. The thin, sinuous posterior portion of the cortex is impacted while the thick anterior portion is snapped in two. The proximal fragment, on which most of the body weight rests, consists of the head, neck, and calcar femorale. This wedge of bone separates

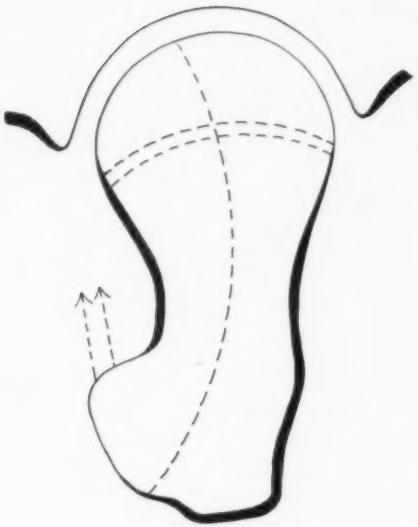

FIG. 7

FIG. 8

Fig. 7: Line drawing of a longitudinal section through the neck of a femur in an adolescent. The external rotators are indicated by arrows.

Fig. 8: A drawing of a specimen showing how the calcar causes splitting of the lateral fragment.

the thin-walled intertrochanteric crest and the lesser trochanter posteriorly from the thick-walled shaft. In some cases, a longitudinal split also occurs on the lateral side of the femoral diaphysis, and in many cases the lesser trochanter breaks off as a separate fragment attached to the psoas major (Fig. 8). In so-called impacted fractures, the spike of the calcar is impaled in the upper portion of the femoral shaft.

The fragments of the thick anterior broken portion of the cortex are held in apposition by the overlying soft tissues, especially by the iliofemoral ligament of Bigelow. The fracture line provides the axis for the characteristic external-rotation deformity of the lower limb which occurs following trochanteric fracture. Normally, the axis of rotation of the femur passes through the head and lower condyles, but in the presence of a trochanteric fracture the axis of rotation is approximately parallel to the shaft. This external-rotation deformity is aggravated by the action of such muscles as the pectineus and the adductors.

The trabecular bone in the femoral head is sufficiently condensed to hold firmly any well placed pin or nail. In contrast, the bone in the neck region, in which there are few or no trabeculae, cannot give adequate support against transverse forces [4] and the only rigid contact for the pin in the outer fragment is the cortical bone of the lateral portion of the shaft. In the head fragment the so-called bull's-eye or centrally placed pin is solidly gripped, but in the outer fragment there is only the one point of firm contact, the lateral cortex of the shaft. It is true, of course, that as a result of the irregularity of the fracture line in the neck, the fragments may become locked, but that locking cannot withstand the transverse shearing forces caused by the surrounding muscles and possibly also by the body weight. Pin movements in the lateral fragment can be reduced or eliminated by inserting the pin so that it rests solidly on the pressure buttress of cortical bone at the upper-medial end of the femoral shaft. The tone of the local muscles prevents the development of valgus deformity.

This discussion has deliberately avoided mention of using screw-plate fixation in addition to pin fixation, for such a procedure involves problems not covered by this paper.

Adolescent coxa vara occurs typically about the age of twelve. Not until the approach of puberty does the subcapital epiphyseal plate, by rotating to an almost vertical position, become exposed to shearing forces. The anterior convexity of the neck together with the backward projection of the intertrochanteric crest gives the lateral rotators a definite mechanical advantage in rotatory movements of the hip joint. This factor, combined with the posterior tilt of the subcapital epiphyseal plate, produces the lateral-rotation deformity which is an early and characteristic feature of adolescent coxa vara. This bony displacement can be best seen in lateral roentgenograms.

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Surgical Approaches to the Vertebral Bodies in the Cervical and Lumbar Regions*

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For the past decade at The Johns Hopkins Hospital, there has been an increasing interest in, and experience with, direct surgery for early positive diagnosis and treatment of lesions of the vertebral bodies. In a comparative review of such lesions, it was found that many early diagnoses could be proved, that diagnostic errors could be discovered in time for salvage, and that a more rapid healing of inflammatory lesions, particularly of tuberculosis, could be achieved [4]. Several surgical approaches have been found useful and may be worthy of recording at this time not because they are original but because their adaptation to surgery of the vertebral bodies may not be generally appreciated.

The techniques and indications for costotransversectomy and lateral rachotomy have been well described [1, 8, 12], but little mention has been made of the open surgical approaches to the cervical and lumbar regions of the spine. While it is not the purpose of this paper to compare direct surgery with needle or trochar biopsy [2, 13], the reasons for preferring open surgery to the trochar or needle biopsy should be mentioned. The principal disadvantages of the punch biopsy seem to be the danger of unknowingly perforating vital structures, the difficulty in obtaining adequate or representative biopsy material, the lack of visualization of the pathological condition *in situ*, and the inability to clean out, to curette, or to excise the lesion. It is felt that careful direct surgery carries little, if any, greater risk to the patient and that direct surgery is more effective in diagnosis and treatment. In a period of more than ten years, there has not been a death as the result of any of these procedures, even though many of the patients subjected to these procedures were considered poor surgical risks.

PHARYNGEAL APPROACH TO THE UPPER CERVICAL VERTEBRAE

The bodies of the upper two or three cervical vertebrae are more superficial than any of the rest; yet, the pharyngeal approach has not been popular because of the apparent danger of secondary infection. Since antiquity, posterior pharyngeal abscesses have been stabbed locally, but this route of exposure through the mouth for treatment of lesions of the first, second, and third cervical vertebrae has not, to our knowledge, been widely used.

Dr. Samuel James Crowe, late Professor of Laryngology and Otology at Johns Hopkins, recalled many cases of tuberculous spondylitis with retropharyngeal abscesses which he had successfully drained, in the period before the discovery of antibiotics, without spread, secondary infection, or even sinus formation. His explanation for this paradox was that there seemed to be a certain local resistance of the tissues within the mouth to its own bacterial flora. The pharyngeal incision has been useful not only for drainage of abscesses but also for more extensive surgery of the upper cervical vertebral bodies themselves. In the case to be presented — a patient of Dr. R. W. Johnson and Dr. S. J. Crowe — a large tumor of the second and third cervical vertebrae was resected.

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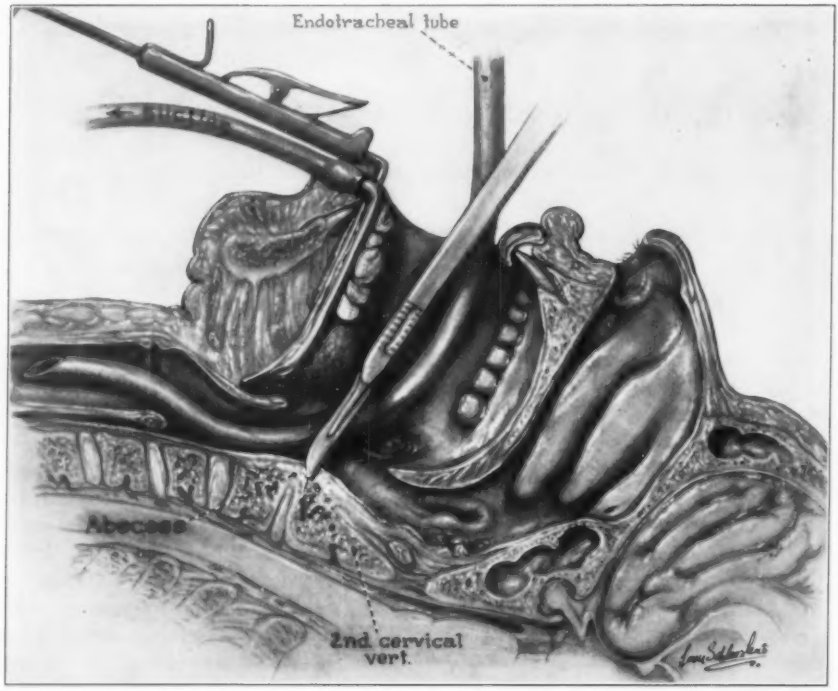

FIG. 1

The posterior pharyngeal incision demonstrates the accessibility of the first, second, and third cervical vertebrae from the pharynx.

Technique

Several important details must be carefully followed before making a pharyngeal incision (Fig. 1). Anaesthesia may be a difficult problem when dealing with a large retropharyngeal abscess. Usually oral endotracheal intubation under topical anaesthesia is safe, but if there is danger of perforation of an abscess during intubation, tracheotomy should be done. No procedure should be attempted without endotracheal intubation or without adequate suction. A non-collapsible tube with a Davis-Crowe mouth gag will provide adequate room for surgery. It is important that the patient be placed in the Trendelenburg position, for, even though an inflated tube is used, material may pass into the lungs around any tube regardless of the method used to close off the trachea.

Sodium pentothal with nitrous oxide has been most commonly used for anaesthesia. A mid-line longitudinal incision is carried through the mucous membrane and the fascial planes directly down to the mass, or to the bone, care being taken that the incision is long enough for adequate exposure of the lesion and drainage of the abscess. Small bleeders may be ligated with fine absorbable sutures. The mid-pharynx is usually avascular and does not bleed excessively. Following the procedure, local instillation of penicillin and streptomycin and closure with one or two interrupted sutures have been very satisfactory. Small abscess drainage incisions should be kept open with a small rubber drain. The drain should be attached to a heavy piece of silk which is then passed through the nose and taped to the cheek in order to keep the drain in place. A large abscess drainage incision may need to have a suture at each pole; the center, however, should not be closed. The incision should be carefully watched for premature closure, and it should be reopened if accumulation occurs. At the close of the procedure, the nasopharynx should be thoroughly

FIG. 2-A

FIG. 2-B

Fig. 2-A: Osteoma of upper cervical vertebra removed through the pharynx.
Fig. 2-B: In the twelve years after removal of the tumor, there has been no appreciable regrowth.

cleaned by suction, as there is usually a large collection of material which would pass into the trachea when the patient is moved from the Trendelenburg position.

Complications

Dr. Crowe and Dr. Williams could not recall a serious complication from use of this procedure, although lack of attention to any of the precautions listed could be disasterous. Opening of an aneurysm could also occur; for this reason the mass should always be palpated and aspirated before incision. Other possible complications are failure to recognize a peritonsilar abscess or extension of the infection into the mediastinum. Care in drainage, avoidance of undue trauma, and confining surgery to the mid-line should avoid these complications.

Case Report

J. H. H. No. 338553, a man twenty-one years old, had severe neck pain following an accident in which his head had been driven through the top of an automobile. Finally, for intractable pain, a fusion of the cervical spine had been performed. Two years later, a very large bone tumor growing from the body of the second cervical vertebra was found (Fig. 2-A). On December 2, 1944, tracheotomy was performed and an osteoma, weighing twenty grams, was removed, without complication, through the pharynx. There has been no appreciable regrowth in twelve years (Fig. 2-B).

ANTERIOR APPROACH TO THE BODIES OF THE CERVICAL VERTEBRAE

Even though in fresh cadavera all of the bodies of the cervical vertebrae can be approached from the anterior aspect of the neck, the pharyngeal exposure is a more simple and direct route for the first and second cervical vertebrae, as has been demonstrated. The following approach has been used successfully for surgery of the bodies of the third cervical to the first thoracic vertebra.

Although the origin of the incision is unknown, this exposure has been widely used for lesions of the esophagus. Lahey and Warren described a similar incision as used in their two-stage excision of diverticulum of the esophagus. Robinson and Smith have recently used the exposure successfully in a series of interbody arthrodeses of the cervical vertebrae. Anterior exposure of the spine seems to be regarded as a dangerous procedure because of its proximity to many vital structures. This impression arises because the approach is usually made posterior to the sternocleidomastoid. The following suggested

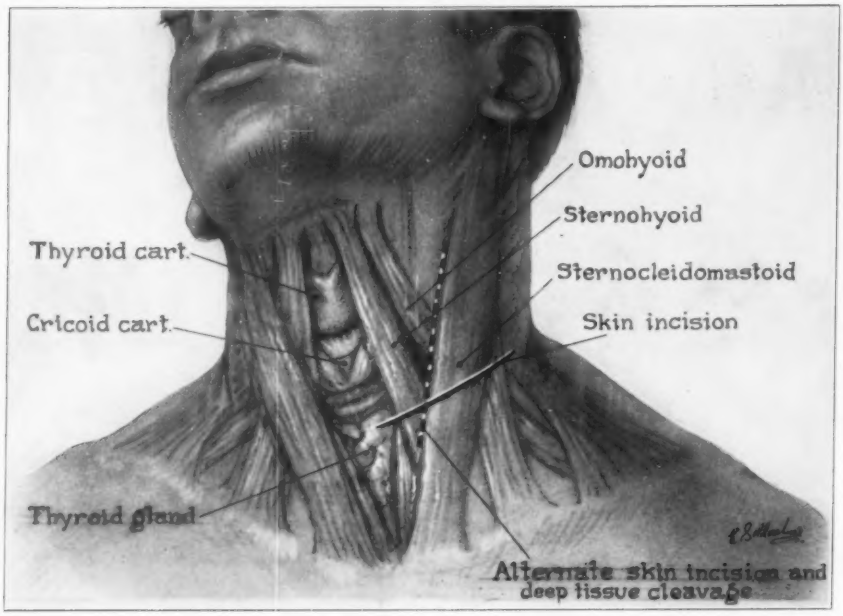
Omohyoid
Sternohyoid
Thyroid cart.
Sternocleidomastoid
Cricoid cart.
Skin incision
Thyroid gland
Alternate skin incision and deep tissue cleavage

FIG. 3-A

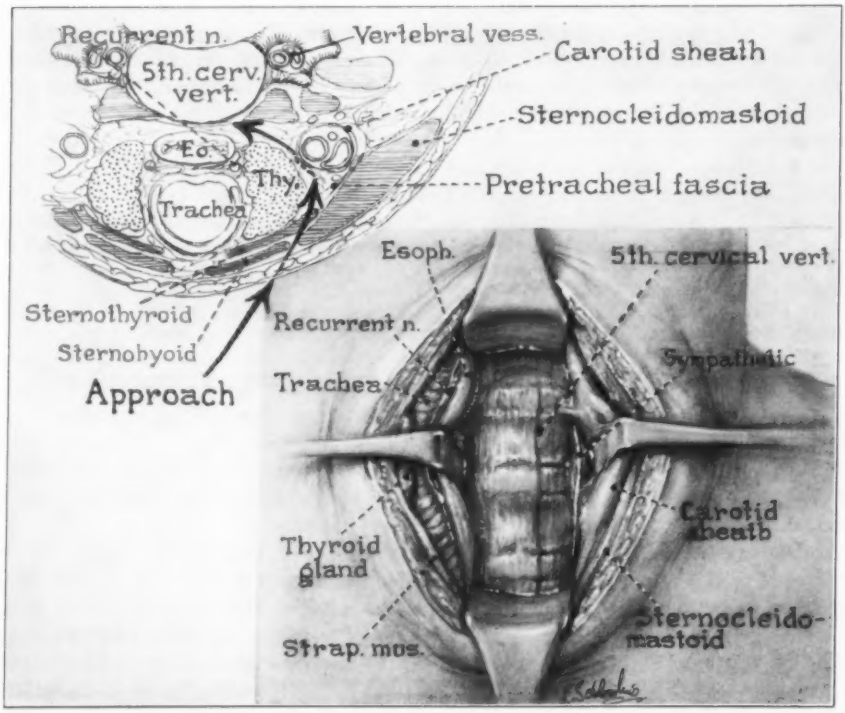
Recurrent n.
Vertebral vess.
Carotid sheath
5th. cerv. vert.
Sternocleidomastoid
Eo.
Thy.
Pretracheal fascia
Trachea
Esoph.
5th. cervical vert.
Sternothyroid
Recurrent n.
Sternohyoid
Sympathetic
Approach
Trachea
Carotid sheath
Thyroid gland
Sternocleido-mastoid
Strap. mus.

FIG. 3-B

approach, anterior to the sternocleidomastoid, has been used by the Resident House Staff with no difficulty and with no permanent adverse effects. As with any surgical dissection, a knowledge of the anatomical landmarks is a basic requirement for the safety of the patient; yet any one capable of handling and recognizing tissues during surgery should have few problems. In the case to be presented drainage and curettage of a rather extensive cervical tuberculous spondylitis was done. The beneficial effects of an early thorough cleaning out of tuberculous cavities as an integral part of the treatment of osseous tuberculosis is demonstrated. Curettage has become at this hospital a part of initial therapy and is used in addition to rest, antibiotics, arthrodesis, and other generally accepted therapeutic adjuvants.

Technique

For all operations on the cervical spine, endotracheal anaesthesia is used in order to prevent obstruction to the airway and to give more adequate room for the skin preparation and proper draping. The area from the mandible to well below the clavicles is prepared and the neck may or may not be draped free. Usually it is only necessary to use a head roll in order to keep the hair out of the field of operation, to drape off a large square with towels, and to use a thyroid-type draping sheet. The patient's head may best be placed on a head rest in slight to moderate hyperextension and with the chin turned slightly away from the site of operation. Usually it is preferable to work from the left side of the neck, there being less chance of injury to the recurrent nerve, although the right side has been used without difficulty on several occasions.

A transverse incision is made at the level of the cricoid cartilage in a skin crease (Fig. 3-A), care being taken to avoid the anterior jugular vein and its transverse anastomosis. The incision is begun at the mid-line and is extended for a distance of about three or four inches — well over the belly of the sternocleidomastoid muscle. The platysma is cut in the same line as the skin incision.

The pretracheal fascia is incised longitudinally, slightly lateral to the mid-line over the sternohyoid and sternothyroid muscles well above and below the site of proposed biopsy, so as to lie medial to the carotid sheath. The sheath is easily palpated, as are the anterior portions of the bodies of the cervical vertebrae. This incision is made by means of scissors dissection and a finger is held on the carotid sheath so as to guard it against injury to its contents. The recurrent nerve descends along the carotid sheath and ascends in the groove between the trachea and esophagus.

The trachea, esophagus, and thyroid are gently retracted medially with a thyroid retractor, and the carotid sheath is gently retracted laterally either with a thyroid retractor or with the fingers (Fig. 3-B). Medial to the carotid sheath, the vertebral bodies are again palpated through the prevertebral fascia to be certain of remaining near the mid-line. Then a longitudinal incision is made with scissors in the prevertebral fascia over the vertebral bodies. The anterior longitudinal ligament which covers the bodies of the vertebrae is seen and may be opened longitudinally with a scalpel. Centrally, there is no muscle covering the vertebrae. Laterally, the longus colli fibers cover the vertebrae and the transverse processes; these should not be disturbed since sympathetic fibers lie in this region.

It is possible to approach the region of the third cervical to the first thoracic vertebra by this approach with little difficulty. For the extremes of this interval, the transverse skin incision may be slightly elevated or lowered, or a vertical skin incision may be made along the anterior border of the sternocleidomastoid, particularly if the extent of the lesion is unknown. In the lowest approach the sternal insertion of the sternocleidomastoid may be cut transversely.

Identification of the level can be made by means of a lateral roentgenogram in the operating room. Other aids to localization are the cricoid cartilage which is usually opposite

FIG. 4-A

FIG. 4-B

Fig. 4-A: Note the forward displacement of the trachea as well as bone destruction.

the body of the sixth cervical vertebra and the carotid tubercle (Chassaignac's tubercle), which is on the anterior aspect of the transverse process of the sixth cervical vertebra. This is the most prominent transverse process posterior to the sternocleidomastoid in the lower part of the neck.

Complications

There have been four complications from the use of this exposure. In one patient, the esophagus was perforated. The surgeon did not properly identify the mid-line of the vertebral body or retract the esophagus before opening the prevertebral fascia. No serious damage resulted after careful suture of the esophagus, although the procedure was delayed until healing had occurred. The esophagus can be identified by its muscle fibers and soft consistency and should not be confused with the prevertebral fascia.

The vertebral artery was perforated once as a result of failure to identify exactly the mid-portion of the vertebral body anteriorly before exposure of vertebral structures was accomplished. The bleeding was controlled by a small gelfoam pack placed in the foramen. No adverse cerebral effect resulted and the operation was not delayed.

The third complication was temporary paralysis of the recurrent nerve. This complication can be avoided by gentleness in retraction, both on the paratracheal and carotid-sheath structures.

A fourth complication, the production of Horner's syndrome, followed irritation or damage to the sympathetic-nerve fibers which arose cephalad from the stellate ganglion and lay with the longus colli muscle in the angle between the body and transverse process. This should not occur if the longus colli is undisturbed or if it is retracted subperiosteally by the mid-line incision.

Although the complications have been pointed out so that others may avoid them, this exposure is remarkably direct, simple, and useful.

Case Report

J. H. H. No. 684444, a colored housewife, twenty-eight years old, was admitted in October 1954 because of severe pain in the neck, difficulty in swallowing, and a hard swelling of the neck. The initial clinical diagnosis of carcinoma of the thyroid was later changed to the diagnosis of tuberculosis (Fig. 4-A). Plaster shells were made. Streptomycin was given for a few days before operation and biopsy of the mass was done. At

operation 300 cubic centimeters of tuberculous exudate was evacuated. The carious vertebrae were carefully curetted, the abscess wall was biopsied, and streptomycin was instilled locally. A small rubber drain was left in place for ten days. Two and a half weeks later a posterior spine fusion from the fourth cervical to the first thoracic vertebra was performed under local anaesthesia; autogenous iliac bone was used and the patient lay in an anterior plaster shell. She was immobilized in a head and body cast for six months and was then gradually mobilized. Antituberculosis drugs were given for twenty months. She has been asymptomatic for over a year and is presently leading a normal life as a housewife (Fig. 4-B).

ANTEROLATERAL APPROACH TO THE BODIES OF THE LUMBAR VERTEBRAE

This exposure to the lumbar vertebrae is a modification of the method used by many general surgeons for the excision of the lumbar sympathetic chain. At first, the technique for lumbar sympathectomy [9,11] was used; this allowed biopsy of the bodies of the fourth and fifth lumbar vertebrae. It was found that a modification of this exposure in which resection of a portion of the twelfth rib [3,7] was done would permit biopsy of the bodies of the first to fifth lumbar vertebra.

The authors wish to point out that this procedure is facilitated by use of a Finochietto rib retractor between the thorax and iliac crest. Thus a much wider exposure of the vertebrae is accomplished and considerably more working room is made available. This approach is especially suitable for excision or thorough curettage of a psoas abscess as it is possible to view all of the lumbar vertebrae and the psoas muscle on the side operated upon.

When a lesion occurs in the front of a vertebral body in proximity to the aorta and vena cava, it is obviously better to have an adequate exposure not afforded by punch-biopsy methods or the posterolateral approach. It is particularly useful when the need for a thorough cleansing is suspected preoperatively or when excision of a vertebral lesion and filling of the defect with bone chips is desired.

Technique

The patient is placed on the table with the side to be operated upon tilted up at an angle of 35 degrees by supporting the shoulder and hip on sandbags. The arm on the side operated upon is carried across the chest and is supported.

An incision is started over the outer one-half of the twelfth rib and is carried obliquely downward and forward in the direction of the fibers of the external oblique muscle to the lateral edge of the rectus abdominis. The end point is usually about one-half way between the umbilicus and the symphysis pubis.

The distal one-half of the twelfth rib is resected subperiosteally and the external oblique muscle is split in the line of its fibers. The internal oblique and transversalis are cut across their fibers in the same oblique line as the skin and the external oblique. Care should be taken to avoid cutting the nerves.

After the muscles have been cut, the retroperitoneal space is entered by reflecting the peritoneum with fingers (Fig. 5-A). This is not difficult if the reflection is begun at the upper pole of the incision where the rib has been partially resected. A common mistake is to reflect the retroperitoneal fat with the peritoneum; this leads to a blind space posterior to the psoas muscles. The fatty layer should be separated from the peritoneum and the peritoneal layer followed down to the anterior aspect of the psoas and bodies of the vertebrae. When the dissection is made difficult by the depth of the wound, a rib retractor placed between the crest of the ilium and the eleventh rib will give wide exposure without effort or trauma and will make visualization and exposure of the vertebral bodies much more simple. With the aid of a Dever retractor in the lower pole of the incision protected with a Mikulicz pad, the peritoneum may be retracted medially. A Dever rectractor may also be used with care to retract the great vessels. The vertebral bodies may be safely palpated from the twelfth thoracic vertebra to the lower prominence of the fifth lumbar vertebra at the entrance of the pelvis. The vertebral bodies are partially covered by the

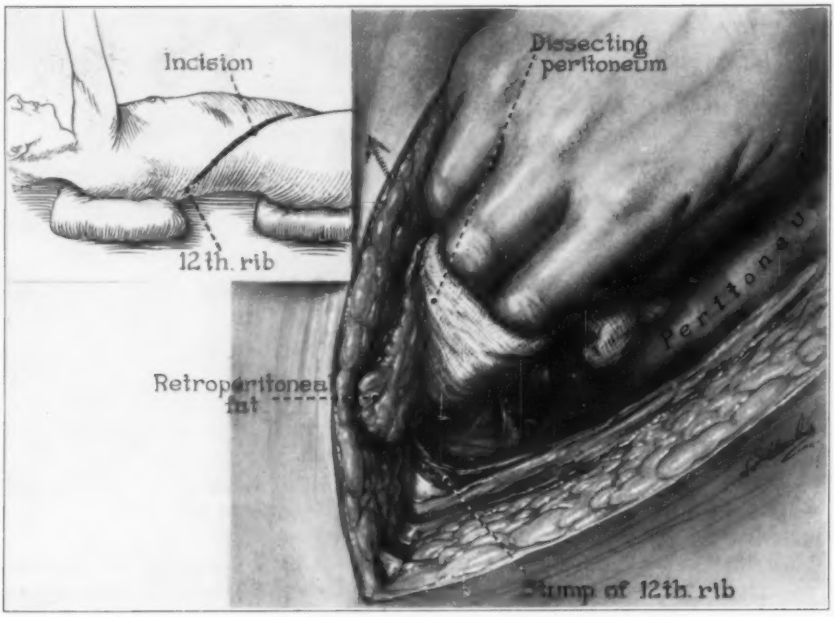

FIG. 5-A

Drawing shows the separation of the retroperitoneal fat and the peritoneum, which leads to the anterior psoas and vertebra.

great vessels and it is necessary to reflect by blunt dissection the vena cava on the right and to a lesser degree the aorta on the left. In all dissection of the vertebrae, the vessels are anterior and should be retracted by the assistant's fingers or by a covered retractor. Adequate exposure and careful dissection is necessary in order to avoid perforation of the lumbar veins or to avoid severe injury to the aorta, vena cava, or iliac vessels. The lumbar veins should be isolated, cut, and ligated or clipped with silver clips when they overlie the lesion. The sympathetic chain is seen along the lateral portion of the bodies of the vertebrae and fibers may be cut or retracted over the lesion; damage to the sympathetic chain has not been a problem.

The bodies of the vertebrae, unless grossly diseased, are covered with the powerful longitudinal ligaments and small slips of muscle attachments of the psoas. The intervertebral discs stand out prominently, and in the grooves between them are the vertebral bodies. It is a simple matter to palpate the prominence of the fifth lumbar vertebra and from this point to identify the desired level. It may be necessary to cut a portion of the longitudinal ligament and to strip the psoas attachments in order to visualize the bone itself (Fig. 5-B). Drills, probes, and curettes may be used directly on the lesion as indicated.

Biopsies, performed through small sympathectomy incisions, are often difficult or dangerous because of inadequate exposure, especially at the first and second lumbar vertebrae. A pararectal incision[5] has a similar disadvantage in addition to the increased difficulty with retraction of the peritoneum and the great vessels.

Complications

No serious complication has resulted from use of this procedure. In one patient, a perforation of the left iliac vein caused considerable blood loss and required suture, but the patient suffered no ill effects. The peritoneum was inadvertently opened on

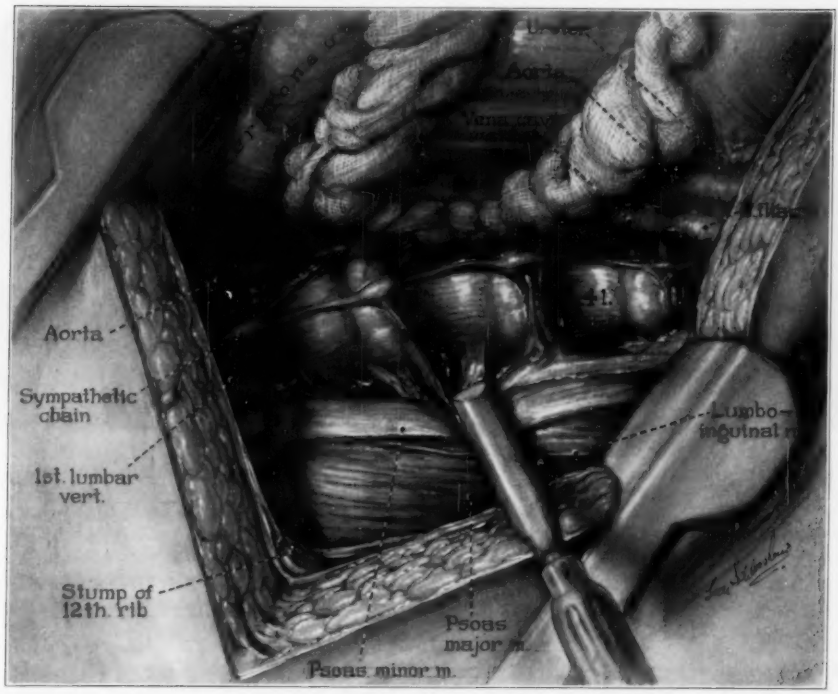

FIG. 5-B

Drawing demonstrates the detachment of psoas fibers and the position of the retractors in exposure of the lumbar vertebrae.

FIG. 6-A

FIG. 6-B

Fig. 6-A: On the left, the catheter can be seen where it passed up the sinus tract from the thigh.

Fig. 6-B: The partial collapse of the twelfth thoracic vertebra can be seen in this roentgenogram made shortly after costotransversectomy on the left and excision of the psoas abscess on the right. The paper clip was taped to the back as a marker for localization.

FIG. 6-C

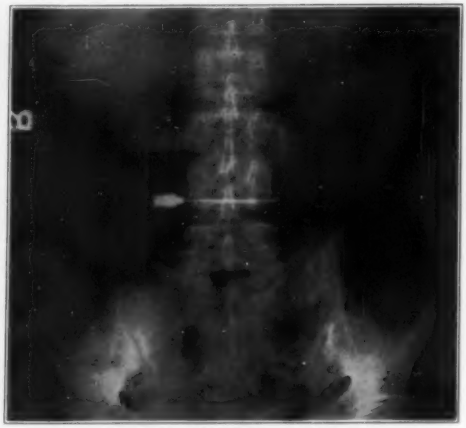

FIG. 7-A

Fig. 6-C: The silver clips denote the extent of the bone graft. At this time there was apparent solid fusion and the patient was clinically well.

Fig. 7-A: Marker roentgenogram made in the operating room. A needle was taped to the back at the probable site of the lesion as a marker.

several occasions and required suture, but this was not attended by an adverse reaction. Irritation of the crus of the diaphragm was thought to be the cause of prolonged hiccups in one patient. The twelfth intercostal and iliohypogastric nerves were cut but did not cause any complaint by the patient.

A sympathectomy effect to the leg will result from manipulation of the sympathetic chain; this has not, however, been permanent. Postoperative ileus occurred in several patients but was not severe or prolonged.

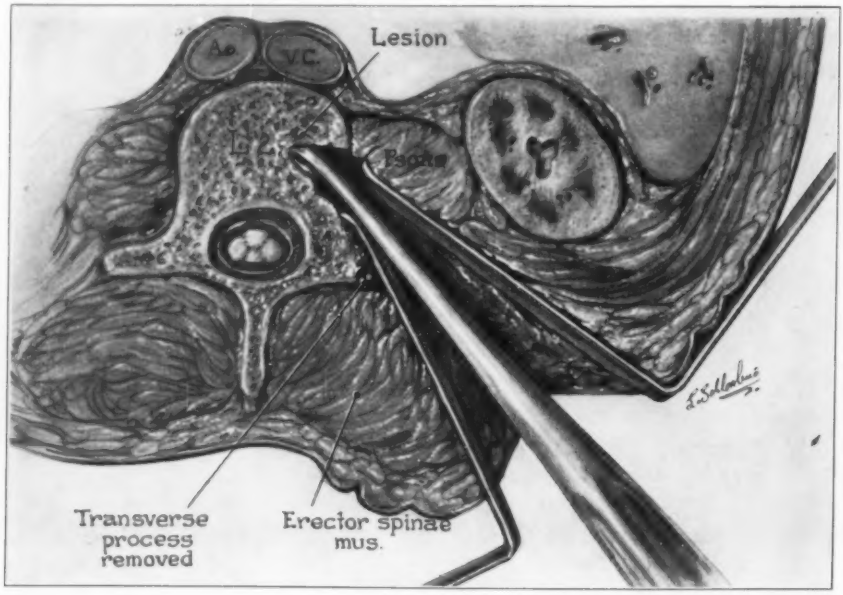

FIG. 7-B

The transverse process has been excised. However, it can often be osteotomized and not detached from the muscle.

FIG. 7-C

FIG. 7-D

Fig. 7-C: Roentgenogram made in the operating room shows the relationship of the curette to the lesion.

Fig. 7-D: Lateral roentgenogram showing the curette within the lesion at operation.

Case Report

J. H. H. No. 666117, an eighteen-year-old Negro man, had, for about two months, noticed a gradually enlarging mass in his right groin; this had been "lanced" at another hospital. His weight had dropped from 145 to 126 pounds in six weeks, and the wound had continued to drain thin exudate. He admitted to having had only three to four days of pain and aching in the left flank and low back. Roentgenograms and sinus-tract injection (Fig. 6-A) showed bilateral psoas abscesses and partial destruction of the twelfth thoracic and the first lumbar vertebrae (Fib. 6-B). After a few days of treatment with streptomycin and para-amino-salicylic acid, a costotransversectomy was performed for drainage and curettage of the abscess on the left. Then the patient was repositioned and an anterolateral exposure of the lumbar vertebrae was performed for excision of the psoas abscess on the right. In both wounds, streptomycin was locally instilled and drains were left in place.

A few days following the drainage his fever subsided and his general condition improved. He was maintained on a full dosage of antituberculosis drugs and was immobilized in plaster shells. The drains were removed in ten days and the drainage sites promptly healed. He was transferred to a tuberculosis sanatorium and was re-admitted ninety days later for posterior spine fusion. One year after the fusion he was asymptomatic and wore a Bennett back brace (Fig. 6-C).

POSTEROLATERAL APPROACH TO THE LUMBAR VERTEBRAE

Because the anterolateral exposure of the lumbar vertebrae seems to be a rather extensive operative procedure for biopsy of certain early or small lesions, another means of obtaining biopsy material was sought which would allow accurate localization, adequate visualization of the lesion, and sufficient material for biopsy and yet be more adaptable for the poor surgical-risk patients and for those in whom the need for wide excision was not apparent.

For lesions along the posterior disc margins of the vertebral bodies, a laminectomy, routine disc excision, and bone biopsy might be considered. However, this has the disadvantage of potential spread of an infectious lesion into the spinal canal, and it does not allow for a thorough inspection or curettage—except in the case of marginal lesions or disc lesions. For these reasons, the laminectomy approach has a limited place in vertebral biopsy. The technique of this method has been well described in relation to excision of intervertebral discs[12].

A posterior approach passing through the erector spinae mass has not been satisfactory. Difficulty with retraction through a thick muscle mass, additional bleeding, and difficulty in finding anatomical landmarks make this a relatively inferior method to the posterolateral approach which passes lateral to the sacrospinalis muscles. This approach is an extension of a method formerly used for piercing a paravertebral abscess and is similar to a costotransversectomy.

FIG. 8-A

FIG. 8-B

Technique

The patient is placed either in the full lateral or anterior position over an x-ray cassette holder so that localizing roentgenograms can be made in the anteroposterior and lateral planes during the operation. If the lateral position is used, the incision side should be up. It is also a good policy to make an anteroposterior roentgenogram with a skin marker taped at the proposed level (Fig. 7-A) and with the patient positioned prior to anaesthesia. This is done for more accurate localization of the incision and to standardize x-ray technique prior to anaesthesia.

If the face-down position is used, endotracheal anaesthesia is essential; it is also desirable for the lateral position.

After the localization roentgenogram is available, the patient is anaesthetized and the exact position of the marker scratched on the skin. Then a four-to-six inch longitudinal incision is made at the lateral border of the erector spinae muscles carefully centered on the biopsy level (Fig. 7-B). The dissection carefully follows the lateral fascial boundary of the sacrospinalis muscle. The fascia is well developed; and, if it is carefully followed, it will lead down to the transverse process of the vertebra. The lateral half of the transverse process is cut free with an osteotome and is retracted laterally. Then, with a periosteal elevator held against the pedicle and stump of the transverse process, the quadratus lumborum and psoas major are carefully separated from the vertebra. Care must be taken to look for and to avoid the lumbar nerves as they pass through the foramina above and below the pedicle. Anterior to the pedicle of the body of the involved vertebra, an opening in the vertebra may be made with a curette or drill. Usually the lesion will have been identified by this time, but it is well to verify the exact site of the lesion in relation to the curette by roentgenograms (Figs. 7-C and 7-D). With such an approach, specimens from both the center and periphery of the lesion may be obtained. The wound may or may not be drained, depending upon the findings; an abscess should usually be drained.

Complications

There have been no serious complications. Difficulties most likely to be encountered are injury to a lumbar nerve and inability to find the lesion.

Case Report

J. H. H. No. 136505, a sixty-year-old white diabetic woman, suddenly had such severe pain in the back that she could not walk. She crawled on her hands and knees to her bed. After three weeks, she was admitted to the hospital because of extreme pain, debilitation, and fever; she was partly disoriented. Roentgenograms showed a destructive lesion at the third lumbar vertebra and terminal metastatic carcinoma was suspected (Fig. 8-A). Supportive measures were given, and biopsy was performed (Figs. 7-A, 7-C, and 7-D) by means of the posterolateral approach. The biopsy specimen showed chronic granulation tissue and from it hemolytic *Staphlococcus aureus* was cultured. Following surgery and penicillin and streptomycin therapy, her condition improved rapidly; two weeks after the biopsy a hemispine fusion, first to fifth lumbar vertebra, was performed. She was maintained in a body cast for four months and has been in excellent health since (Fig. 8-B).

SUMMARY

Four surgical approaches to the vertebral bodies have been developed which, in conjunction with costotransversectomy, allow surgical access to all portions of the bodies of the vertebral column.

The pharyngeal incision is used for the first and second cervical vertebrae. The anterior cervical approach is used for lesions from the third cervical to the first thoracic vertebra.

Costotransversectomy and lateral rachotomy are used for lesions of the first thoracic to the twelfth thoracic vertebra, inclusive. The anterolateral approach is used to gain access to the first to fifth lumbar vertebra and allows excellent visualization and treatment, particularly of extensive lesions. The posterolateral approach is less formidable and is sufficient for treatment of a small lumbar lesion.

In a period of over ten years, there has not been a death from the use of these surgical approaches, and serious complications have been avoided. Use of the approaches has been highly effective not only in obtaining early positive diagnosis of vertebral lesions but also in their definitive treatment.

NOTE: The authors wish to express their gratitude for the helpful advice and assistance of Mr. Leon Schlossberg, medical illustrator; Dr. J. T. H. Johnson; Dr. George Smith; Dr. Lee Williams; Dr. Samuel Crowe; and particularly Dr. Robert W. Johnson, Jr., who originally kindled our interest in this type of direct surgery and performed many of the early operations.

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DISCUSSION

Dr. W. Gordon Murray, Toronto, Canada: Naturally the discussion will arise whether a posterior spine fusion is adequate and whether an interbody fusion is any better. In spine deformity, it has been my experience that by pressure from without and within, some correction of the deformity of bodies can be obtained. This correction can be maintained by intervertebral blocks until fusion occurs. By repeated operations further corrections can be effected, when growth and molding of the soft tissues and thoracic cage have accommodated themselves to the new shape and stresses.

There are other advantages of vertebral-body fusion. I have found that it is quite safe to get the patients up walking and home, within ten days to two weeks, without any external support. They recover rapidly without great financial loss. My approach differs slightly from Dr. Southwick's. I have found that by rotating the chin fully to the opposite side, an incision made posterior to the sternocleidomastoid will expose the anterior surface of the transverse processes. It is made to follow the fascial plane from the superficial layer inward, and it extends anterior to the scalenus anticus, longus coli, transverse process, and brachial plexus directly to the bodies of vertebrae. The only structure encountered which must be protected is the spinal accessory nerve. In the upper part, the sensory divisions of the third and fourth cervical nerves can be retracted or divided at will without any resulting disability. The carotid sheath and all visceral structures lie in front, leaving the bodies of vertebrae exposed with good visualization. In my experience in making an incision anterior to the sternocleidomastoid (which is the case in approaching the upper end of the esophagus or the lower end of pharynx for retropharyngeal biopsy) there are periods when the recurrent laryngeal nerve is in danger. Considerably more dissection is required than is required in making the incision posterior to the sternocleidomastoid. I am sure, however, that through either one an adequate exposure can be obtained. Through my approach there is no difficulty whatever in taking out cervical discs, in applying bone grafts in the space, in wedging the vertebrae open, and in applying suitable wedges to maintain the correction.

I agree entirely with Dr. Southwick that a lateral incision with a retroperitoneal approach for exposure of the lumbar vertebrae comes down directly on the body of the vertebra. If there is no other indication, I prefer to do this on the left side because the aorta stands retraction and handling better than does the inferior vena cava. Through this approach, I have had no difficulty in removing intervertebral discs and applying grafting wedges for correction and strong interbody fusion.

It was suggested by the chairman that I take a moment to comment on the approach to the thoracic vertebral bodies. All thoracic vertebral bodies can be approached without difficulty. Through the intercostal approach, the lung is reflected, and, on opening the pleura, the whole thoracic spine lies within one's reach. The space selected can be up or down from the fourth vertebra in the upper area and the seventh and eighth thoracic vertebrae in the lower area. The sympathetic chain lies in the field; this either can be sacrificed if necessary or can without difficulty be retracted. Some of the white rami communicantes and splanchnic nerves sometimes require division; this will cause no ill effect. Through this approach, one can, with external pressure, obtain considerable correction of deformities of the thoracic spine; and, with wedges between the vertebrae, one can obtain good opening of the spaces. This is done after the intervertebral ligaments are divided. It is easily demonstrated how pressure will open concave areas of spine. The intervertebral disc must be completely removed and then the enlarged space must be filled with compact bone — either autogenous or homogenous bank bone. In some cases, rib bone is good enough, but in others it is too soft and will collapse under too much pressure and, will, therefore, not maintain a corrected position. After the grafts have been inserted, I like to pin them in position by bone pegs inserted well into the adjacent vertebral bodies which transfix the graft. These are so secure that no graft has slipped.

Dr. Robert W. Johnson, Jr., Baltimore, Maryland: I remember twenty or twenty-five years ago attempting to approach the vertebral bodies transabdominally and having a retractor on the aorta pull out a lumbar vessel. It was a hole and I was a Dutch boy at the dike. I had my finger on the aorta over the hole. We did not have in our kit adequate suture material and clamps to deal with such a serious contingency and had to wait quite a while before we could adequately close it. I would like to suggest that in the lower lumbar region, the vena cava and the common iliac vein can be compressed by the retractor and not look like vessels at all; these can be opened in an attempt to expose the common ligament. There will be a lot of hemorrhage which can eventually be controlled. Such a complication cannot be foreseen; although complications have been surmounted and no deaths have occurred, it is essential to have a good road map. This is essentially what this paper is. It demonstrates the necessity for an exposure extensive enough so that serious complications may be avoided.

Osteo-onychodysplasia

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This interesting syndrome involving the patella was first described by Little in 1897, at which time he reviewed forty-two cases in which there was absence or hypoplasia of the patella. Mention was also made of a family in which eighteen members representing four generations lacked both patellae and thumbnails. In 1933, Turner described a combination of arthrodysplasia and dystrophy of the nails which had been found in twenty-six members of a family of thirty-nine. In 1948, Mino and his associates, in a review of the literature, presented reports of at least 100 similar cases.

This group of deformities has been described by a number of synonyms, including osteo-onychodysplasia, arthrodysplasia, onychochondrodysplasia, onycho-arthro-osteodysplasia, and Turner's syndrome.

Dystrophy of the nails is the most frequent of the deformities in this syndrome. This disorder varies from almost total absence of the nail to a nail that is scarcely distinguishable from normal except that it is too thin. The thumbnail is usually the most affected, the deformity becoming progressively less marked from the first to the fifth fingers. The typical dystrophic nail has a small base that is much thinner than normal, and it gradually terminates at about the middle of the nail bed, allowing the fleshy end of the finger to turn backward over its end. This affliction makes picking up pins or other thin objects difficult or impossible.

The deformities of the knee are usually characterized by hypoplastic or rudimentary patellae which are displaced upward and laterally. The medial condyle may be prominent,

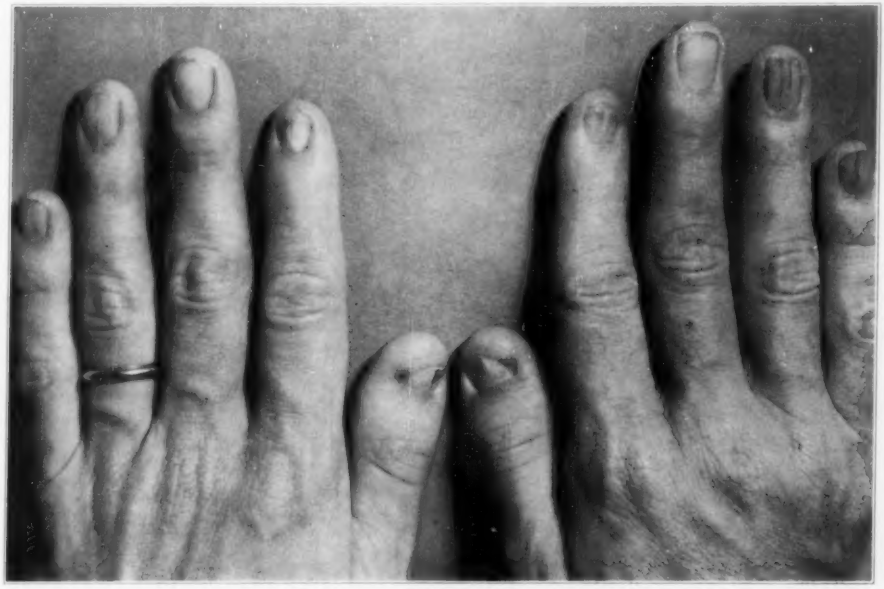

FIG. 1

Bilateral involvement of the thumbnails with minimal changes in the other nails.

FIG. 2

FIG. 3

Fig. 2: Anteroposterior and lateral roentgenograms of the right arm showing the abnormal length of the proximal end of the radius which is dislocated posteriorly.

Fig. 3: Anteroposterior and lateral roentgenograms of the left arm showing malformation of the radial head and hypoplasia of the capitellum.

FIG. 4

Anteroposterior and lateral roentgenograms of the right knee showing hypoplasia of the patella which is displaced upward and laterally. An area of osteochondritis dissecans may be seen in the medial femoral condyle.

and a varying degree of genu valgum may be present. The deformity is often associated with weakness of the quadriceps femoris as well as with pain and discomfort secondary to arthritic changes. These conditions are usually the source of the major complaints by patients with this syndrome.

Deformities of the elbow joint consist of thickening of the distal portion of the humerus and prominence of the medial epicondyle. The radial head is small and deformed and is usually subluxated or dislocated posteriorly. Clinically there is limitation of flexion, extension, supination, and pronation; and the carrying angle is increased.

The other commonly prominent feature in this syndrome is the presence of iliac horns which are palpable over the posterior iliac region and are quite apparent in roentgenograms.

Other less common deformities encountered are pes planus, prominence of the

medial malleoli, prominence of the distal end of the clavicle, underdevelopment of the scapula and humeral head, and coxa valga.

Hereditary arthrodysplasia rarely occurs independently of hereditary dystrophy of the nails. Indisputable evidence of the hereditary nature of these defects is provided by the family histories given in most of the cases reported in the literature. It is generally felt that this trait follows the Mendelian Law and that it is dominant.

FIG. 5

Anteroposterior and lateral roentgenograms of the left knee showing hypoplasia of the patella which is displaced upward and laterally. Several loose bodies are present.

FIG. 6

Anteroposterior roentgenogram of the pelvis. The arrows indicate the iliac horns.

FIG. 7

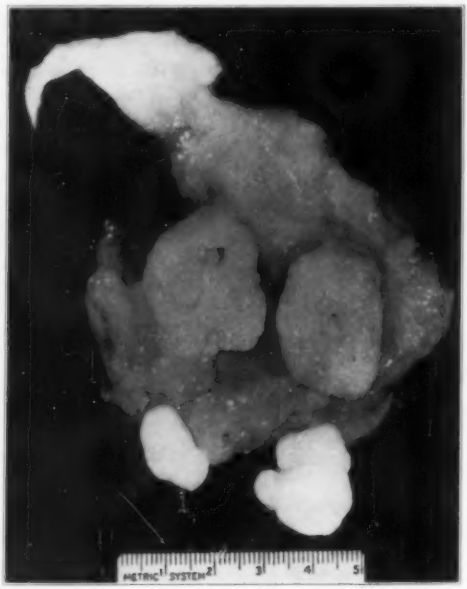

FIG. 8

Fig. 7: Oblique roentgenogram showing the iliac horn on the right side.
Fig. 8: Photograph showing the thickened synovial membrane and multiple loose bodies taken from the knee.

In the following case, fifteen members of the patient's family representing five generations have had varying forms of the syndrome.

CASE 1. P. O. S., a white man, twenty-eight years old, was seen because of persistent pain and weakness in the left knee. He stated that he had had limitation of motion in both elbows, flat feet, and deformity of the right knee for as long as he could recall.

Physical examination revealed a slender, well developed man who was five feet, seven and one-half inches tall. Observation of the patient standing revealed no abnormalities of the back, but palpation revealed bilateral bone prominences over the posterior iliac area. Motion of the back was within normal limits, and there was nothing unusual about the shoulders and the scapular area. There were definite abnormalities of both elbows, consisting of enlargement of the medial epicondyles and prominence of the radial heads. On the right side the radial head appeared to be subluxated or dislocated posteriorly, and on the left it was more prominent than normal. Motion of the elbows was limited in flexion and extension. The hands and wrists were normal with the exception of the nails, which were small and thin and had longitudinal ridges (Fig. 1). The major abnormalities of the lower extremities were limited to the knees. In the right knee the patella was small and was displaced upward and laterally. Motion was normal, but crepitation was present. The contour of the left knee was fusiform, there was increased joint fluid, and the patella was displaced upward and laterally. There was also crepitation on motion, and loose bodies could be palpated. In both extremities there was moderate pes planus, and the medial malleoli were more prominent than normal.

Roentgenographic study of the elbows revealed that the radius in the right arm had an abnormally long proximal end and that it was dislocated posteriorly (Fig. 2). In the left arm the radial head was malformed and the capitellum was hypoplastic (Fig. 3). The roentgenograms of the knees revealed bilateral hypoplasia of the patella with lateral dislocation (Figs. 4 and 5). In the left knee several loose bodies were seen. Roentgenograms of the chest and skull showed no bone abnormalities, but those of the pelvis revealed bilateral iliac horns (Figs. 6 and 7).

Exploration of the left knee was carried out through a parapatellar incision. It was found that the patella was hypoplastic and that several cartilaginous bodies were present, encapsulated in synovial tissue (Fig. 8). Débridement was carried out, the hypoplastic patella being left in place. There was hypertrophic lipping on the femoral condyles.

The two children of P. O. S. were examined; in both evidence of the syndrome was found.

FIG. 9

Photograph of the hand of P. C. S. showing involvement of the nails of all five fingers.

P. C. S., born August 19, 1951, was seen in consultation two days following delivery. Increase in the carrying angle of the elbows was noted. On repeat examinations the following deformities were noted to have progressively developed: calcaneovalgus deformity of the feet, deformity of the nails (Fig. 9), bilateral displacement of the patella, and increase in the carrying angle of the elbows. Roentgenographic examination of the child at the age of four years showed slight subluxation of the radius at the radio-ulnar joint of the right elbow. The roentgenographic appearance of the knees was not unusual except that the patellae were not visible. The pelvis showed no abnormalities.

The second child, G. D. S., born February 20, 1955, had dysplasia of the nails of the thumb and index finger. There was bilateral calcaneovalgus deformity of the feet and increase in the carrying angle of the elbows. Roentgenographic study made at the age of six months revealed that the left elbow was normal but that in the right arm there was posterior dislocation of the radius at the radio-ulnar joint. The appearance of the knees was not unusual; the patellae were not visible at this age. An anteroposterior roentgenogram of the pelvis showed bilateral iliac horns.

The mother of P. O. S., Mrs. S. S., aged seventy-one, was unable to appear for examination, but roentgenograms and photographs were submitted. From this evidence it appeared that she had characteristic deformities of the nails, especially the thumbnails, deformities of both elbows, and bilateral hypoplasia of the patellae. Roentgenograms of the arms showed bilateral deformities of the radial head with dislocation of the radius in the left arm. Roentgenograms of the pelvis showed congenital deformities of the lumbar spine but revealed no evidence of iliac horns.

In addition to the members of this family, we have studied one other patient with this syndrome.

CASE 2. C. A., a white man, sixty-one years old, was first seen in this institution in 1953, because of intestinal obstruction due to an incarcerated hernia. Special roentgenographic studies were carried out because of the presence of bone abnormalities, but nothing further was done at that time.

Later the patient was recalled for examination. He was working as a farmer and had no complaints except occasional weakness in the left knee.

Physical examination revealed a fairly well developed man. Observations made while he was standing revealed a scoliosis to the right and moderate dorsal round-back. The positive physical findings were mainly limited to the extremities. There was prominence of the radial head in the right arm with limitation of motion in supination and pronation. In both elbows flexion and extension were limited to between 40 and 175 degrees, but there were no other abnormalities except bilateral prominence of the medial epicondyle. There was deformity of the nails, most marked in the thumb; and there were definite deformities in both knees: the medial condyles were prominent and the patellae were small and were displaced laterally. There was prominence of both medial malleoli. Bilateral iliac horns were palpable.

Roentgenographic studies revealed the characteristic findings of hypoplasia of the patellae, iliac horns, and deformities of both elbows.

No definite history could be obtained from this patient as to whether other members of his family were or had been affected by this syndrome.

SUMMARY

Osteo-onychodysplasia (Turner's syndrome) is a familial disease which is inherited and which is characterized by a number of deformities. The principal deformities involve the fingernails, elbows, patellae, and ilia. The symptoms causing the patient to seek medical advice are usually pain and discomfort in the knees and limitation of motion at the elbows.

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Fibro-osseous Dysplasia of the Skull

A Case Report

BY NORMAN LENSON, M.D., BROOKLINE, MASSACHUSETTS

The term *fibro-osseous dysplasia* was chosen to designate the condition described in this report in order to avoid neoplastic implication and the problems encountered in pathological classification and pathological and roentgenographic correlation. Hoboeck stated that all types of osteitis fibrosa localisata of the facial bones and the skull are histologically characterized by unspecific reparative tissue which is, basically, fibrous new-bone formation showing varying degrees of maturation but no significant morphological differences. On the basis of fifty-two roentgenographic examinations, he suggested

FIG. 1

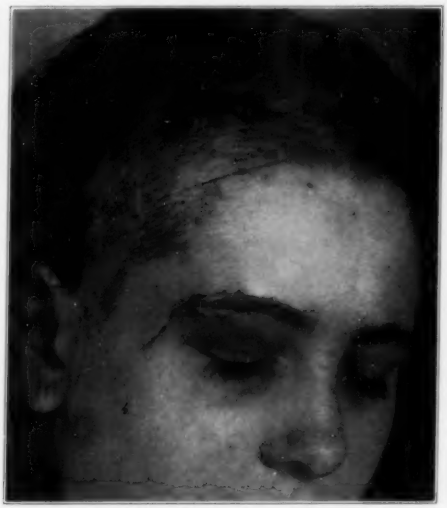

FIG. 2

Fig. 1: The bony, hard tumor masses are clearly seen. Note the elevation of the supra-orbital ridge extending superiorly and inferolaterally. The patient had a slight proptosis of the right eye and she was unable to fully raise the lid.

Fig. 2: The patient seven days postoperatively.

that discrimination between fibro-osteoma, fibrous dysplasia, and osteoma of the facial bones and skull be maintained for the present despite the histological uniformity of these conditions. Eden concluded from his evaluation of this problem that there is a group of benign fibro-osseous tumors of the membranous bones of the skull and face which are not associated with general skeletal disease and which have an essentially similar structure although differing in their clinical and pathological details. He stated that these lesions arise periosteally or subperiosteally early in life in one or more foci and grow slowly before they stop growing. All stages of bone formation in fibrous tissue are found within these tumors, which he classified into four categories: (1) ossifying fibroma, (2) fibrous osteoma, (3) compact osteoma, and (4) diffuse osteoma. He believed that the limitation of the lesions to membrane bone, often in multiple foci, and their frequent origin during the growth period suggest that the lesions are true benign tumors related to the development of membrane bones and that they are comparable to osteochondroma of cartilaginous

bone. Eden believed that some of these localized tumors are caused by chronic infection or injury and that they may represent a fibro-osseous reaction of the bone and periosteum to chronic irritation due to sepsis or trauma.

A ten-year-old white girl was first seen on February 10, 1955, for an evaluation of several bone-hard lesions of the skull and a mass in the neck. Her mother denied that any skull masses were present at birth or shortly thereafter. She stated that when the child was three years old, she struck the right side of her head against a sharp object, resulting in right periorbital and frontal parietal oedema and ecchymosis.

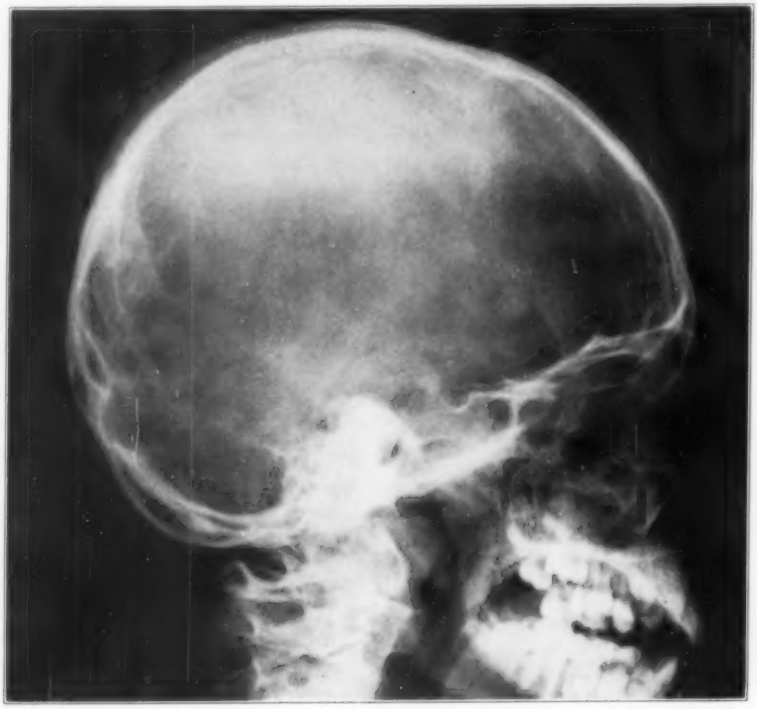

FIG. 3

Roentgenogram of skull. A tumor mass stemming from the external plate is clearly seen at the lambda. Other lesions are not so evident. Note the increased digital impressions.

Three months later, the skull tumors became evident, and a neck mass was noted. Both the skull lesions and the neck mass progressively increased in size.

The mother denied that she had had any significant traumata, illnesses, or medicaments while she was carrying the child. The birth was normal and without instrumentation. The family history was not remarkable. There was no incident of bone abnormality. The child's past history was not contributory, and her system review was within normal limits.

Physical examination revealed an alert youngster with no obvious speech impairments or mental defects.

There were no cutaneous or neurocutaneous lesions. Eight distinct bone-hard tumors were palpable on the right side of the skull (Fig. 1). These measured from one centimeter in diameter to four by 2.5 centimeters and were located at the supra-orbital ridge, the right frontal, the parietal, and the occipital areas. There was a thickening of the skull, two centimeters in width, which extended distally from the right supra-orbital ridge. Palpation revealed a hard mass, 7.5 centimeters by 5 centimeters, in the right side of the neck. The child had scoliosis of the spine with a double curve. There was slight proptosis of the right eye, and one of the tumors interfered with the elevation of the right eyelid. There was an unsustained nystagmus on the left lateral gaze. Examination of the extremities revealed somewhat shortened fifth fingers of both hands. Results of the remainder of the physical and neurological examination were within normal limits.

FIG. 4

FIG. 5

Fig. 4: Roentgenogram of the cervical spine, showing congenital deformity and a bone mass on the right side which appeared clinically as a tumor mass.

Fig. 5: Lateral view of the cervical spine showing irregularity in the size of the vertebral bodies, particularly of the fourth and fifth cervical vertebrae.

Laboratory examination revealed normal blood and urine. Serum calcium was 4.7 milliequivalents per liter, alkaline phosphatase was 7.1 Bodansky units, and serum phosphorus was 5.8 milligrams per 100 cubic centimeters.

Roentgenographic examination of the skull showed increased digital impressions and several small osteomata measuring from one to two centimeters in size in the region of the lambda, the posterior sagittal,

FIG. 6

Photomicrograph of a nodule resected from the outer table of the skull. Subperiosteal fibrosis and deep extension of the fibrous tissue into the bone marrow are seen. Note the fairly broad bone trabeculae, numerous osteocytes, and bone formation.

FIG. 7

A higher magnification of photomicrograph seen in Fig. 6. Increased cellularity of the fibrous tissue can be seen along the upper margin, beneath which there are transitional stages between fibrous tissue and bone. Note the prominence of the osteocytes.

and the right frontal-parietal areas (Fig. 3). The spine showed a loss of normal cervical curve with some reversal of the curve centered on the third cervical vertebra. The body of the third cervical vertebra was small and irregular in shape. The bodies of the second, fourth, fifth, and seventh cervical vertebrae and the first thoracic vertebra were irregularly developed (Fig. 4). There was unilateral widening of the bodies of the fourth, fifth, and sixth cervical vertebrae on the right and of the first thoracic vertebra on the left. There was scoliosis on the right side centered on the fifth thoracic vertebra. Laminagrams of the cervical spine showed a congenital deformity. The right lateral mass of the first cervical vertebra was hypoplastic, and the second cervical vertebra showed a shortened odontoid process. The right lateral mass of the third cervical vertebra was hypoplastic. There was fusion of the left lateral masses of the fourth and fifth cervical vertebrae. The right lateral articulations of the fourth and sixth cervical vertebrae were not developed, and there was fusion of the left lateral articulations of the fourth and fifth cervical vertebrae. There was also incomplete development of the left side of the sixth and seventh cervical vertebrae. The greater bone mass on the right side of the cervical spine resulted in a sharp cervical scoliosis with the apex of the curve on the right side of the fifth cervical vertebra. No other bone abnormalities were noted on roentgenographic examination.

The preoperative diagnosis of the skull lesions was osteoma, and resection of the supra-orbital and frontal lesions was decided upon for cosmetic reasons and to prevent visual impairment. On April 15, 1955, with the patient under general anaesthesia, the lesions were resected through two transverse incisions (Fig. 2), with reflection of the frontalis and orbicularis oculi muscles. The periosteum was sharply incised and reflected, exposing the outer table. The lesions and the supra-orbital ridge, lateral to the supra-orbital foramen, were sharply resected. The lateral inferior margin of resection extended to the zygomatic process. The patient's postoperative course was uneventful and she was discharged on the seventh postoperative day.

The patient was last seen in August, 1956; there was no evidence of recurrence of the lesions.

On pathological examination, the diagnosis was localized developmental abnormality of intramembranous ossification involving dense fibrous tissue and vascular ectasia. Seen microscopically, the sections of tumor consisted of bone trabeculae which were generally broad and homogeneous, in which were found abundant Sharpey fibers. A moderate amount of marrow cellular elements were intermixed with abundant fat tissue. The cellular elements were normoplastic. There was a moderate degree of fibrocollagenous replacement of the marrow immediately beneath the nodule surface. The surface of the nodule consisted of a fairly broad band of cellular fibrocollagenous tissue, beneath which there was moderate thickening of the bone trabeculae associated with some osteoblastic activity. A few of the deep bone trabeculae showed partial erosion and fibrous replacement. There was moderate vascularity with slight to moderate angiectasia. There was no osteoid formation, no inflammation, and no evidence of malignant growth. The nodules which had been removed were similar in appearance, although in some the fibrocollagenous tissue extended more deeply into the marrow than in others, and there was, in some, more osteoblastic activity.

DISCUSSION

The case reported is an instance of fibro-osseous dysplasia of the skull occurring in a ten-year-old white girl who had congenital malformation of the cervical vertebrae and slightly shortened fifth fingers. It is doubtful that the history contributed by the mother is correct, and the probability is that the skull lesions were present at birth. It is equally doubtful that trauma was a factor in the genesis of the skull lesions.

Roentgenographically, the skull lesions were diagnosed as osteoma. The pathological diagnoses varied. The microscopic slides were seen by Dr. Sheldon C. Sommers of the Massachusetts Memorial Hospitals, Boston, Massachusetts, who interpreted the slides as representing localized developmental abnormality or intramembranous ossification involving dense fibrous tissue and vascular ectasia. Dr. John M. Craig of the Children's Medical Center, Boston, Massachusetts, thought that the lesion was not fibrous dysplasia, but rather that some of the areas of mixed fibrous tissue and bone were from skull sutures as such configurations were often found at these sites. A third pathologist returned a diagnosis of osteoma, that is, bone protuberances from the deposition of new bone on the outer table, and diploidization of the new bone.

NOTE: I am indebted to Dr. Manuel Correia-Branco for permission to report this case, and to Mr. Leo Goodman of the Mallory Institute of Pathology, Boston City Hospital, for the photography.

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Retrosternal Dislocation of the Clavicle

BY ARTHUR H. STEIN, JR., M.D., ST. LOUIS, MISSOURI

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Retrosternal dislocation of the sternal end of the clavicle is an unusual injury. It may occur as a result of a blow either on the posterolateral aspect of the shoulder girdle or directly over the sternal end of the clavicle. In 1922, Schlegel collected nineteen cases of this injury and reported a case of his own. Greenlee, who reported a single case in 1944, had been able to find seven additional case reports, most of which were in the German literature. In a review of the literature from 1944 to the present, I have been able to find seven additional case reports of retrosternal dislocation of the clavicle[3, 4, 5, 6, 8, 9].

Since there have been only about thirty-five cases of retrosternal dislocation reported in the literature, it would appear that of all the injuries that occur to the clavicle and its articulations, this is the most rare. During the past two and one-half years, I have seen and treated three patients with retrosternal dislocation of the clavicle. These three cases form the basis of this report.

CASE 1. J. L., an eighteen-year-old white male, in good health, was injured in an automobile accident on December 19, 1953. The patient stated that at the time of the collision his left shoulder was driven forcefully into the driver of the car, after which he noted immediate pain at the base of his neck. He was seen on the night of the accident, at which time examination revealed swelling and tenderness over the left sternoclavicular joint with abnormal motion of the clavicle at its sternal attachment. At the time of the clinical examination, it was thought that the injury was probably a superior dislocation of the clavicle.

On December 22, 1953, an open reduction of the left sternoclavicular joint was undertaken. This was accomplished through an oblique incision made over the sternoclavicular joint. Following exposure, it was found that the anterior and superior surface of the joint capsule was intact, but that there was complete tear of the posterior portion and that the sternal end of the clavicle was lying posterior to the manubrium in the anterior-superior mediastinum. The dislocation had occurred between the clavicle and the articular disc of the sternoclavicular joint. By means of a bone-holding forceps, the clavicle was depressed posteriorly and then lifted easily back into anatomical position. The rent in the posterior capsule was repaired and, in order to maintain the reduction, a braided stainless-steel wire was passed through a drill hole in the clavicle and then around the first rib (Fig. 1). The patient's immediate postoperative course was uneventful.

On August 27, 1956, this patient was re-examined by the author. At that time he was able to do heavy work and had no complaints of pain in the region of the left sternoclavicular joint. He did complain, however, that upon certain motions of the shoulder girdle, there frequently occurred a popping sensation in the region of the joint. Examination revealed that when the shoulder was thrown back, there was a normal relationship between the manubrium and the sternal end of the clavicle, but that when the patient rotated the entire shoulder girdle anteriorly, he could at will reproduce a posterior dislocation of the sternal end of the left clavicle. Roentgenographic examination at this time was not particularly revealing except to show that the wire which had been inserted approximately two and one-half years previously had fragmented in many places. It was recommended that a secondary reconstruction be done, but since the patient was having no pain, he refused further surgery.

CASE 2. J. P., an eighteen-year-old white male, was injured while playing football on December 12, 1953. When tackled, he fell on his right side and immediately had severe pain in his right shoulder. Following this, he noted that when he attempted to take a deep breath, there was pain at the base of his neck to the right of the mid-line.

On examination it was found that the entire right shoulder girdle was rotated in an anterior direction and that it was impossible for the patient to get the right scapular region to touch the table when he was in the supine position. The vital signs at that time were within normal limits. Further examination revealed an absence of the usual prominence of the sternal end of the right clavicle. Instead of this prominence there was a depression in the region of the sternoclavicular joint, and the application of pressure over this area was painful. Attempts to rotate the shoulder girdle posteriorly produced severe pain at the base of the neck. It was also observed that the right clavicle was rigidly fixed. A clinical diagnosis of posterior dislocation of

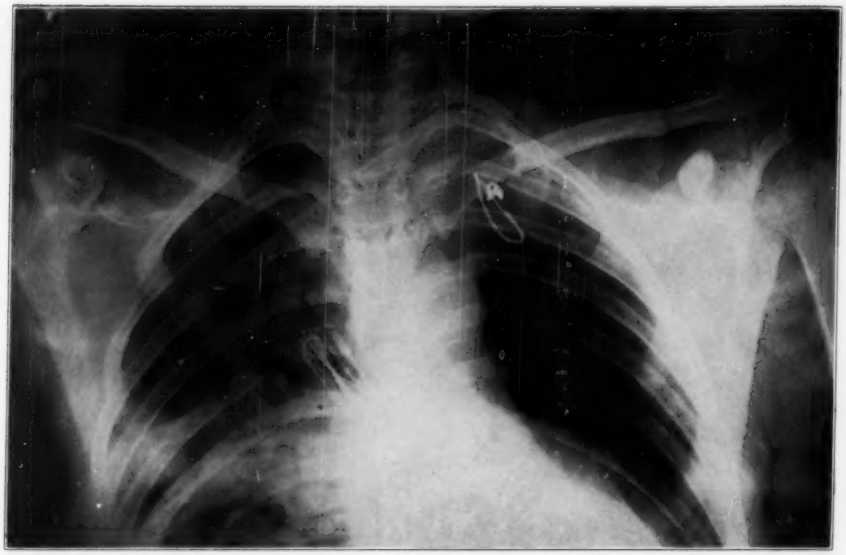

FIG. 1

Case 1. A wire loop, placed around the first rib and inserted through a drill hole in the clavicle, was the method of internal fixation used to secure stabilization of the retrosternal dislocation.

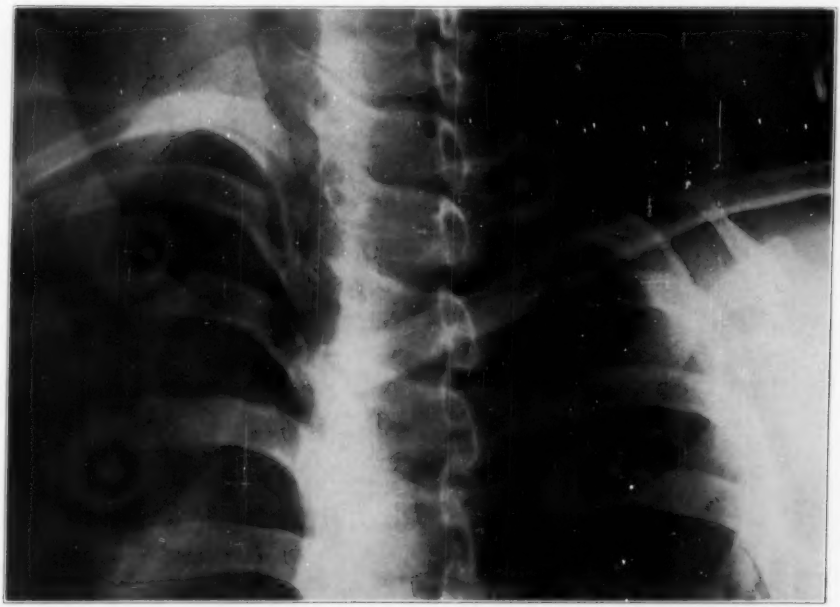

FIG. 2

Case 2. Roentgenogram, made before reduction, showing dislocation of the right sternoclavicular joint.

FIG. 3-A

Case 3. Roentgenogram made before reduction of the right sternoclavicular joint. The shadow of the sternal end of the clavicle is superimposed on the shadow of the manubrium.

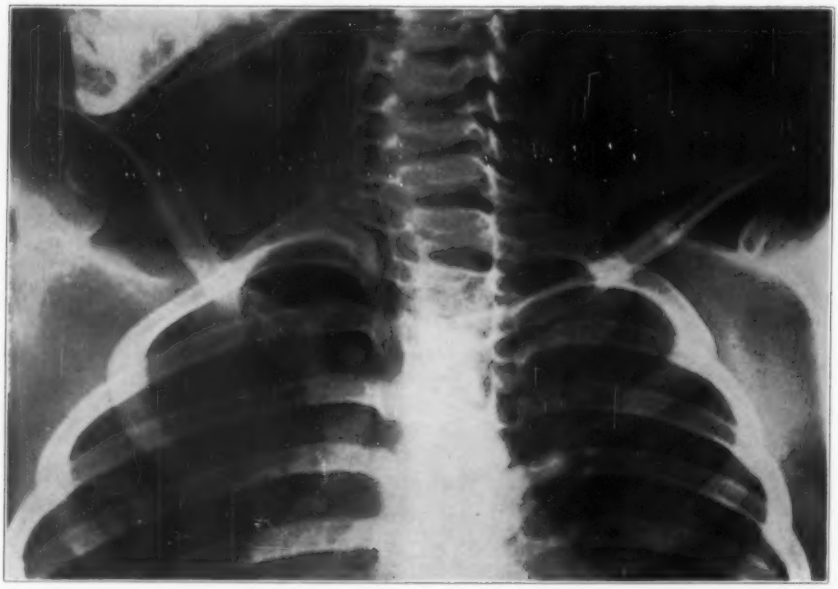

FIG. 3-B

Oblique roentgenogram made almost two years after the injury. Reduction of the dislocation has been maintained.

the clavicle at the sternoclavicular joint was made (Fig. 2). Roentgenographic examination revealed the sternal end of the right clavicle to be displaced so that the clavicle appeared to be superimposed on the manubrium.

The patient was admitted to the hospital, and traction was applied in the following manner. With the patient in the supine position, the shoulder was abducted to approximately 100 degrees in the coronal plane, the elbow being extended. A simple type of skin traction (ten pounds) was then applied to the forearm. In applying the traction, an attempt was made to have the arm supported on the bed with only the forearm and hand extending beyond the edge of the bed. Approximately thirty minutes after the application of the traction, the patient felt a sudden snap and sharp pain at the base of his neck. Examination shortly thereafter revealed that the normal prominence of the sternal end of the clavicle had been restored. The patient was discharged from the hospital on December 16, 1953, with a figure-of-eight dressing which was allowed to remain in place for approximately three weeks. He has not been seen again, but on February 24, 1956, his mother reported that he has been having no difficulty as a result of his injury. He has played professional baseball and at the present time is in the armed forces. A letter from the patient on March 7, 1956, substantiated his mother's report.

CASE 3. S. P., a six-year-old colored male with known sickle-cell anaemia, was struck by an automobile on January 23, 1954. He was seen at another hospital because of pain in the region of the right shoulder, but the parents were told that no injury could be found. Two days later the patient was seen at Barnes Hospital because of continued pain in the region of the right clavicle.

Physical examination revealed slight swelling and tenderness over the right sternoclavicular joint. The sternal end of the clavicle could not be palpated and its usual prominence was absent. When the examiner inserted his finger tip partially behind the manubrium, the sternal end of the clavicle could be felt lying posterior to the manubrium. The nerve supply and circulation to the right upper extremity were normal. The right clavicle was found rigidly fixed in position, and it was noted that the left sternoclavicular joint was more mobile than the right. Roentgenographic examination revealed a consistent depression of the sternal end of the right clavicle. On the roentgenogram the clavicle appeared superimposed on the manubrium (Fig. 3-A), and it was impossible to determine clearly the posterior position of the clavicle. However, on the basis of the clinical examination, a diagnosis of posterior dislocation of the sternoclavicular joint on the right side was made.

The patient was admitted to the hospital and traction was applied in the same manner as in Case 2 (including five pounds of skin traction). Two days later there was complete clinical reduction of the right sternoclavicular joint, the usual prominence of the sternal end of the clavicle being restored. The traction was removed February 1, 1954, and the patient was given a figure-of-eight dressing which he wore for approximately three weeks.

A follow-up examination (including roentgenograms) on March 6, 1956, revealed that the right sternoclavicular joint was essentially normal in both appearance and function (Fig. 3-B).

DIAGNOSIS

The mechanism of injury in these cases was a blow to the lateral aspect of the involved shoulder. A blow directly over the clavicle may also produce a retrosternal dislocation, as has been mentioned by Greenlee. Pain at the base of the neck is usually an immediate manifestation, and pain on deep breathing may also be present.

When the clavicle is displaced in a retrosternal position, it may become fixed; in such cases the abnormal mobility of the clavicle seen in anterior or superior dislocations is, of course, not present. It is apparent from Case 1 that following a primary posterior dislocation the position of the clavicle may shift so that the injury appears clinically to be a superior dislocation. The capsular rent in Case 1 was straight and posterior. In retrosternal dislocations anterior rotation of the involved shoulder girdle gives the patient a "hunched appearance", and any effort to force the shoulder posteriorly causes pain at the base of the neck.

Localized pain is present over the sternoclavicular joint in retrosternal dislocation but the swelling may be minimal compared with that in anterior or superior dislocations. On palpation of the joint the usual prominence of the sternal end of the clavicle will be absent. Following flexion of the neck, however, the clavicle can usually be palpated in the retrosternal position.

We have found that it is difficult to clearly demonstrate the posterior position of the clavicle by roentgenography, for the usual views show the shadow of the clavicle

superimposed on the shadow of the manubrium; for this reason, the retrosternal position of the clavicle must usually be diagnosed from the clinical examination. We did not feel it was necessary to employ laminagraphy in the three reported cases. However, it is possible that by this technique the posterior displacement might be clearly shown (tomography was used in Holmdahl's case).

The severe complications that may occur in association with this injury were not seen in the three reported cases even though one patient reported pain on respirations. Death from retrosternal dislocation of the clavicle has been known to occur as a result of damage to the trachea and great vessels [4]. Respiratory distress, dysphagia, and subcutaneous emphysema following this injury have also been reported.

TREATMENT

In the approximately thirty-five reported cases of this injury, treatment has been by skeletal traction, closed reduction, open reduction, and excision of the sternal end of the clavicle. In two of the cases presented in this report, reduction was accomplished by simple skin traction with the shoulder abducted at about 100 degrees. This treatment was followed by immobilization in a figure-of-eight dressing for three to four weeks. In the past many methods of internal fixation by means of fascia and wire have been used to reconstruct the costoclavicular ligaments. In the author's series the placement of a braided wire loop around the first rib and then through a drill hole in the clavicle gave good fixation at the operating table. A satisfactory result may be obtained by any form of internal fixation that will maintain reduction until the stout costoclavicular ligaments have had a chance to heal. Key and Conwell have stated that the articular disc usually tends to dislocate with the clavicle in the anterior sternoclavicular dislocation. In most of the reported cases of retrosternal dislocation, however, the articular disc has remained attached to the sternum. This was also true in the patient treated by operation in this series.

From the findings in these three cases and in those previously reported, it would seem that conservative management in the form of traction with the arm abducted beyond 90 degrees should be tried. If reduction has not been obtained following the use of traction for forty-eight hours, then open operation and internal fixation should be undertaken.

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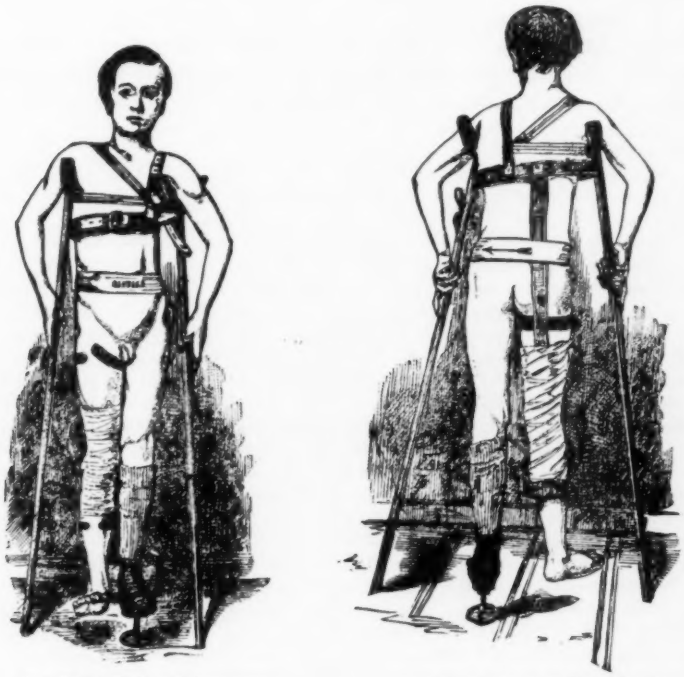
Traction *Versus* Rest in the Treatment of Hip Disease *

BY MATHER CLEVELAND, M.D., NEW YORK, N. Y.

Virgil P. Gibney, in 1884, published *The Hip and Its Diseases.* In the Preface, he stated that during his thirteen years as Resident Surgeon at the Hospital for the Ruptured and Crippled he had seen and treated 2,048 patients with hip disease. The term hip disease was a catchall for such conditions as tuberculosis, suppurative arthritis, coxa plana, congenital coxa vara, and slipping of the upper femoral epiphysis (adolescent coxa vara). Acknowledgment was given in the Preface to the work of Dr. Charles Fayette Taylor, Dr. Adoniram B. Judson, and Dr. Newton M. Shaffer, of New York City, leaders in orthopaedic surgery at that period, and also to Dr. William T. Bull, Dr. C. T. Poore, Dr. John A. Wyeth, and Dr. Frederic S. Dennis, who were leading contemporary general surgeons.

In this book, Gibney described and commented on the Liverpool method of treatment (page 349) as follows: "Mr. Hugh Owen Thomas, of Liverpool, England, has, for a number of years, employed a method of fixation that seems to secure this object better than most of the splints now in use. At the same time, while disavowing any attempt or

352 DISEASES OF THE HIP.



-FRONT VIEW OF MR. THOMAS'S SPLINT APPLIED. —A POSTERIOR VIEW OF THE THOMAS SPLINT.

FIG. 1

These are illustrations of the front and back views of the Thomas hip splint as portrayed on pages 352 and 353 of Gibney's book *The Hip and Its Diseases.*

* This bit of orthopaedic history was prompted by the gift to the author by Mr. Robert A. Gibney of the letter to his father, Dr. Virgil P. Gibney, from Hugh Owen Thomas in May 1889.

desire even at extension [traction], he uses in conjunction with this splint the high shoe [on the opposite foot] and crutches. He certainly takes enough precaution to protect the joint from injury, and the zeal with which he pursues his practice, and the favor it is meeting with throughout Great Britain, bespeak for it more consideration than the surgeons in our own country seem willing to give." Again on page 357, Gibney continues: "The objections urged against immobilization are, to my thinking, without ground, and I believe with Mr. Thomas that the closer one can come to securing perfect rest the better the final result will be. . . . If this plan will secure a movable joint the inconveniences are as nothing. At all events let American surgeons give it a trial." Gibney was thus far more open-minded and fair about the methods of Hugh Owen Thomas than were some of his American colleagues.

The Thomas hip splint was designed to immobilize and rest the affected hip without exerting any traction. It consisted of a flat piece of malleable iron long enough to extend from the lower angle of the scapula to the lower third of the leg. This was carefully shaped over the thorax, buttock, posterior part of the thigh, and calf. To this was riveted at the proximal end a thoracic band, fastened with buckle and strap, and a harness or suspenders over each shoulder. A second band or crescent was fastened to the splint about two inches below the iliofemoral crease. The third band (the calf strip or crescent) was riveted to the distal end of the splint. The splint was padded and covered with leather. When the splint was applied, a roller bandage was used to fix it to the pelvis and to the lower part of the thigh and to the calf. A patten high enough to clear the foot of the diseased limb was applied to the shoe of the sound limb. Crutches were invariably used. Gibney pictures this Thomas splint on pages 352 and 353 (Fig. 1).

The following letter from Hugh Owen Thomas to Gibney written May 9, 1889, expresses the views of the writer on the proper treatment of hip disease and a terse reference to the so-called "American Method" embodying "tractionism" (Fig. 2).

"My dear Friend,

Many thanks, very many, for your kind invitation to visit the U. S. A. Thanks again for your friendly candour, whether my excuse about the Statistics be accepted or not is a matter of utter indifference to me, that I have none to produce is a perfectly true assertion, and that it was not possible for me to have any is nearly as true. A man who during the first ten years of his professional life was engaged from six in the morning till twelve o'clock at night and losing about two night's sleep a week, would not be encouraged to keep trustworthy notes and records of cases. During the following Twenty years engaged from 9 a.m. to 11 p.m., this close application to practical work was still a great bar. My cranium is my note book and with it I will sketch any ideal case that shall be on all four with any real one, I will undertake to give the Symptoms local and as well the characteristic utterances of the patient. I could personally imitate and act the Sufferer. I am by no means anxious to make conversions as I don't think it reasonable to expect to convince in ten years, when it took me twenty *to feel certain*. Congress discussions I think are worthless, for example, Mr. Jones lately accepted a challenge to show *extreme disease, prolonged treatment, with motion remaining* to my annoyance he appealed to me for assistance, loan of cases, etc. When the cases were exhibited as requested, none but 'extreme disease, prolonged treatment with motion remaining' were brought forward — the conditions were filled yet the challengers not dissatisfied with the exhibition as regards results objected to the 'prolonged' item, though it was a main condition. I decided I would never again bother my head about exhibitions. In 1883 the Brit. Med. Assocn. met in this city, and I was asked to exhibit. I said I would do nothing of the sort, as the president of the Surgical Section had treated me and others very badly for many years; two days before the meeting Mr. Edmund Owen the Secy called upon me and prevailed upon me to give a demonstration in my own house. I did, and you will find the record in the Brit. Med. Journal for Aug. 18, 1883. Who the reporter was I don't know, I made one conversion, well worth the trouble I admit. These discussions and demonstrations disturb the even tenor of my way. Bauer converted me to Tractionism and the American method and I converted myself out of it again, and if the 'St. Louis Medical & Surgical Journal' of April 1886 Vol. L No. 4 is true, I drew Bauer after me. I much dislike discussing the question of Instruments, I am willing to stand or fall on the publication of principles which I have made. A thick headed fellow, in American Medical Journal says that I take too Mechanical a view of my subjects, my contention in all I have written has been and still is

Surgeons do take too mechanical a view which I try to avoid. I found fault with practitioners of medicine upon the same line, they take too chemical a view. I know that I figure as a very conceited fellow, a man ought to have some conceit after thirty-two years of close attention to his profession and having spent his youthful days in being innoculated with the very doctrines now generally practised in the U. S. A.

You ask me a question in your letter about Hip joints, by the light of my own experience, they run a shorter course and give *better results* than knees.

With very kind regards from Mrs. Thomas, Mr. Jones and myself I remain one at least contented to be weighed in the Balance of the Future. Yours truly H. O. Thomas"

Within this same year (1889) the Orthopaedic Service of St. Luke's Hospital in New York was completely disrupted by an angry and intemperate controversy over the merits of traction as opposed to rest in the treatment of hip disease. Dr. Newton Shaffer had served as Attending Orthopaedic Surgeon to St. Luke's Hospital since 1872. In 1881, Dr. John Ridlon was appointed Assistant to the Attending Orthopaedic Surgeon at St. Luke's Hospital. In January 1888, Dr. Ridlon was appointed Attending Orthopaedic Surgeon and Dr. Newton Shaffer became Consulting Orthopaedic Surgeon. Ridlon had visited Hugh Owen Thomas and had become interested in his ideas for the treatment of hip disease. Thus the stage was set for the controversy between Shaffer and Ridlon.

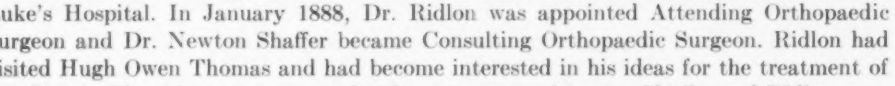


FIG. 2

An excerpt from Thomas' letter to Gibney: "Bauer converted me to Tractionism and the American method and I converted myself out of it again, and if the 'St. Louis Medical and Surgical Journal' of April 1886 Vol. L No. 4 is true, I drew Bauer after me." Louis Bauer, a pupil of Stromyer, practiced orthopaedic surgery in New York from 1852 to 1870, when he removed to St. Louis where he continued a distinguished career in his profession. Of Bauer, Thomas wrote: "In my early life I was, in my practice, a close imitator and an ardent admirer of my friend, Dr. Louis Bauer, the best exponent of American orthopaedics."

The minutes of the Medical Board of St. Luke's Hospital dated December 18, 1888, contain the report (eight longhand pages) of a committee consisting of Dr. L. B. Bangs, *Chairman*, Dr. A. Brayton Ball, and Dr. Robert Abbe, which had been set up to deal with the controversy between Shaffer and Ridlon. Dr. Shaffer had accused Dr. Ridlon of deviating from the rigid application of the "American Method" in the treatment of hip disease on the wards of St. Luke's Hospital. "He charges that if Dr. Ridlon by using the Thomas splint is in direct antagonism with the 'American Method' which has been regarded as the method of treatment in St. Luke's and, for the amplification of which he declares Dr. Ridlon to have been appointed as his successor, then he can no longer work in harmony with Dr. Ridlon nor be considered responsible for the Orthopaedic Department at St. Luke's."

The views of the two principals in the dispute were fully given in the report of the committee. "Dr. Shaffer defines the 'American Method' as follows: 'Its essential principle is that of traction, i.e., an apparatus is so adjusted as to the articulation (joint) that a pulling or separating force is exercised upon the inflamed articular surface.' He adds: 'By this means, contact of the diseased surfaces is avoided, and involuntary spasm of the muscles controlling the joint is antagonized, and ultimately overcome, without, however, increasing the inter-articular (i.e., between the surfaces of the joint) pressure.'" (Fig. 3). Dr. Ridlon's definition of the "American Method" is: "The principles of this method were *motion* and *traction* obtained by use of a portative apparatus. This method, as a method, he says is no longer generally employed. The method which Dr. Shaffer has called the 'American Method', and which is today pretty generally accepted by American Orthopedic Surgeons, has for its general principles,

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FIG. 3

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other methods have reduced the deformity, such as recumbency, and "traction in the line of deformity", which is evidently quite in accord with the practice of Dr Shaffer.

Dr Ridlon gives an explanation of what he understands by the "American Method", and to which he refers in his publications as the "American Method", as follows:

"The principles of this method were motion and traction obtained by the use of a portative apparatus. This method, as a method, he says is no longer generally employed. The method which Dr Shaffer has called the "American Method", and which is today pretty generally accepted by American Orthopedic Surgeons, has for its general principles,

1. Fixation, or immobilization.
2. Traction.
3. Removal of the superincumbent weight.

These principles Dr Ridlon accepts,

FIG. 4

FIG. 3: An excerpt from the minutes of the Medical Board of St. Luke's Hospital, New York City, December 18, 1888 — that part of the investigating committee's report which defines in Dr. Shaffer's own words the "American Method" for the treatment of hip disease.

FIG. 4: A further excerpt in which Dr. Ridlon's understanding of the "American Method" is stated in his own words:

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1. Fixation or immobilization.
2. Traction.
3. Removal of the superincumbent weight.

These principles Dr. Ridlon accepts." Dr. Shaffer was further reported to have said: "There is nothing in the whole range of orthopaedic practice like the portative traction apparatus if properly adjusted. Dr. Ridlon stated that 'he had used the Thomas splint in two cases and tried it in six or eight more'. In support of his principles Dr. Ridlon has submitted to the committee letters from prominent orthopaedic surgeons in this country and different parts of the world in order to show that there is not a unanimity of opinion among these gentlemen as to the method to be employed in the treatment of these diseases."

The "American Method" of treating hip disease was not a single uniform method. Splints designed to exert traction on the hip joint were devised by Bauer, Washburn, Hutchinson, Sayre, Taylor, Shaffer, and Judson, as well as many other contemporary orthopaedic surgeons.

The most successful of these splints was devised by Charles Fayette Taylor—this one met with the approval of Newton Shaffer. This consisted of a pelvic band, a long side bar extending to well beyond the foot, ending in a broad foot piece. The side bar was hollow distally and contained an inner bar with teeth which could be extended by a ratchet key and locked when sufficient traction was exerted. Two mole-skin adhesive plasters were cut in an elaborate pattern and applied to the thigh and leg of the affected side. Each of these moleskin strips ended distally in a buckle—to be attached to a strap on either side of the foot piece. Counter traction was obtained by two perineal straps fastened to the pelvic band. The shoe on the sound side was elevated.

The Taylor traction hip splint is portrayed in Gibney's book on page 368 (Fig. 5). The foot piece of the splint was worn inside a shoe. Because of the elevation of the opposite shoe, theoretically no weight was borne by the affected limb. Crutches might or might not be used.

When the author first went to the New York Orthopaedic Hospital, he saw several of these Taylor traction hip splints in use on children with tuberculosis or chronic suppurative arthritis of the hip joint.

The committee report continued to observe: "The methods of these two gentlemen, Dr. Shaffer and Dr. Ridlon, are not essentially far apart. It appears to be a question of professional difference more than one of principles, and your committee does not feel called upon to decide between two gentlemen where both seem to be so remarkably in the right, and so humane in their efforts to relieve the sufferings of the unfortunate cripples committed to their care. . . . In the treatment of these chronic joint diseases Dr. Ridlon has shown himself skillful, intelligent and faithful. In saying this your committee would by no means disparage Dr. Shaffer or discredit his long and arduous service but without prejudice would desire to point out that the best interests of this great hospital viz. benevolence and science are often best subserved by leaving *freedom of choice* in method to the humanity and skill of the attending surgeons."

Following this meeting of the Medical Board of St. Luke's Hospital where the committee report had been accepted with thanks, Dr. Shaffer made a special report on the situation to the Board of Managers of St. Luke's Hospital, by-passing the Medical Board to their obvious annoyance. The Medical Board then through the same committee reported to the Board of Managers, opening with the following: "Certain statements

made by Dr. Shaffer seem to reflect upon the judicial fairness of this Board in its investigation of the controversy between Dr. Ridlon and himself." Dr. Shaffer had complained to the Board of Managers of Dr. Ridlon's "almost habitual rejection of my advice while making my weekly advisory visits". No such complaint had been made to the Medical Board and they resented the fact "that a member of the staff should have been subjected

368 DISEASES OF THE HIP.

THE TAYLOR SPLINT APPLIED.

FIG. 5

This is an illustration of the Taylor traction hip splint portrayed on page 368 of Gibney's book *The Hip and Its Diseases.*

to so serious an accusation without an opportunity to refute it" and that "the Board itself should have been placed in the embarrassing position of having rendered a verdict without a full presentation of the charges by the complainant". This report was dated

February 2, 1889, and later that year in a minute of the Medical Board dated October 23, 1889, there appears: "Further that an extension of privileges of Consulting Surgeons in Special Departments creates a conflict of services and disorders the internal arrangements of the hospital in a way detrimental to its best interests." This may be interpreted as an expression of the Medical Board's determination to have no further meddling on the part of a consulting staff.

It is a matter of record that Dr. Ridlon served only one year as Attending Orthopaedic Surgeon at St. Luke's Hospital. The minutes of the Medical Board contain no mention of Dr. Ridlon's resignation or dismissal. The first mention of his successor, Dr. T. Halstead Myers, is the simple note of his presence at a meeting of the Medical Board on September 23, 1890. The minutes failed to reveal any mention of Dr. Myers' appointment as Attending Orthopaedic Surgeon. Dr. Shaffer continued as Consulting Orthopaedic Surgeon at St. Luke's Hospital for forty years after this controversy. Dr. Ridlon left New York for Chicago.

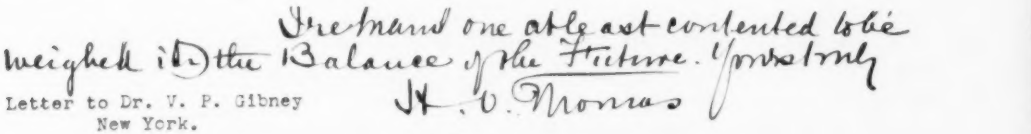
I remain one at least contented to be
weighed in the Balance of the Future. Yours truly
Letter to Dr. V. P. Gibney
New York.
H. O. Thomas

FIG. 6

The final sentence in Thomas' letter to Gibney: "I remain one at least contented to be weighed in the Balance of the Future."

Few, if any, living orthopaedic surgeons can possibly appreciate the intensity of feeling for a given method of splinting. The controversy over the efficacy of the "American Method" so bitterly waged by Newton Shaffer is an indication of his conviction and also an indication of his character. He seems to have been lacking in ability to see the possibility that a differing opinion might have some merit or truth in it. The committee of the Medical Board at St. Luke's Hospital summed it up: "It appears a question of professional difference more than one of principle." Hugh Owen Thomas also had no qualms about his views when he ended his letter to Gibney: "I remain one at least contented to be weighed in the Balance of the Future." (Fig. 6).

Of the four orthopaedic surgeons mentioned, Hugh Owen Thomas, Virgil P. Gibney, Newton Shaffer, and John Ridlon, each made a distinct contribution to his surgical speciality.

Thomas of Liverpool has always been considered the dean of orthopaedic surgery of his time. He was a man of small stature but of great intellect. His outstanding trait was the infinite pains he took in the care of his patients. He was the lineal descendent of Hunter and Hilton in their conception of the importance of rest in healing. Sir Arthur Keith has said: "Hugh Owen Thomas believed that an overdose of rest was impossible." His ideas and influence perhaps came to fuller fruition through his distinguished nephew and successor, Sir Robert Jones.

Gibney served as Surgeon-in-Chief to the Hospital for the Ruptured and Crippled from 1887 to 1924. He acted as President of the first meeting of The American Orthopaedic Association and was elected President in 1912. He was a distinguished teacher with devoted pupils.

Shaffer, the first elected President of The American Orthopaedic Association, served for twenty-one years as Surgeon-in-Chief of the New York Orthopaedic Hospital, resigning after a controversy with the Board of Trustees. He then founded the New York State Reconstruction Hospital in Haverstraw. While he was instrumental in gaining recognition for orthopaedic surgery as a specialty of medicine, he stoutly opposed the performance of any surgical procedure by orthopaedic surgeons.

Ridlon, after leaving New York City, had a long and distinguished career as an orthopaedic surgeon in Chicago. In 1894 he was elected President of The American Orthopaedic Association. He too was a splendid teacher with devoted pupils.

Each of these surgeons, except Thomas who died in 1891, in his fifty-seventh year, survived to achieve old age. Gibney died at eighty in 1927, Shaffer at eighty-two in 1928, and Ridlon at eighty-four in 1936. Probably the least well known by present-day orthopaedic surgeons is Newton Shaffer.

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2. Keith, Arthur: Menders of the Maimed, p. 36. London, Oxford University Press, 1919.

A Technique for Accurate Localization of Vertebrae at Surgery

BY D. KAY CLAWSON, M.D., AND DON KING, M.D., SAN FRANCISCO, CALIFORNIA

From the Department of Bone and Joint Surgery, Stanford University Medical School, San Francisco

The difficulties in locating a given vertebra on the operating table are well known to all who do spinal surgery. It is often impossible to state with any assurance which of two or three vertebrae is the one containing the lesion to be biopsied or to be fused. In

Fig. 1

Fig. 2

Fig. 1: Anteroposterior roentgenogram showing Kirschner wire in the spinous process of the second lumbar vertebra.

Fig. 2: Lateral roentgenogram showing Kirschner wire in place. Note that it is directly opposite the involved intervertebral joint space.

order to overcome this difficulty, many techniques have been devised. We have found most of them to be cumbersome or to be lacking the accuracy of localization so important to the surgeon. In an effort to find a completely satisfactory method of marking a vertebra, we have used a Kirschner wire drilled into the spinous process and then cut off subcutaneously. This method has proved so satisfactory that we would like to present it to others.

Our procedure is as follows: The patient's back is prepared the day before surgery, and again on the morning of surgery. A small hand drill, a medium-size Kirschner wire, end-biting wire cutters, and a skin tray are placed at the patient's bedside. The patient is placed in the prone position and the spine at the appropriate level is identified as accurately as possible by palpation. The area is cleansed with aqueous zepherin in 1 to 1000 solution, and the skin and fascia over the chosen spinous process are infiltrated with two cubic centimeters of 1 per cent novocain. After the spinous process has been encountered, the Kirschner wire is drilled into it about a half an inch. There has been no difficulty locating the spinous process with the Kirschner wire, but a small hand drill that will allow for accurate control is essential. The skin is then depressed with the wire cutter and the wire is cut. The skin is allowed to rebound, and the small puncture wound is sealed with collodion. The wire is thus subcutaneous and the patient's movement continues uninhibited. Anteroposterior and lateral roentgenograms are made and it is then possible to identify the involved area with absolute accuracy by the location of the wire (Figs. 1 and 2). It makes little difference if the wire is placed one level higher or lower. At surgery, the wire is exposed and left in the spinous process until the area of surgery has been delineated.

We have used this technique routinely at the Stanford University Hospital for two years without any untoward effects. It is rapid, taking less than five minutes of the surgeon's time. It requires little equipment and is an extremely simple procedure. It eliminates chance of error without introducing into the body a substance that cannot be readily removed. It offers no more danger of inducing infection into the wound than a needle puncture in a properly prepared field. These advantages, combined with its unparalleled accuracy, leads us to believe that this technique should have wider acceptance.

An Effective Laminotomy Rest

BY LOUIS SCHEMAN, M.D., AND SAMUEL H. FRAERMAN, M.D., HIGHLAND PARK, ILLINOIS

From the Department of Bone and Joint Surgery, Northwestern University Medical School, Chicago, and Highland Park Hospital Foundation, Highland Park

For the past seven or eight years we have used an original laminotomy rest or pillow for performing herniated-disc surgery. Although similar pillows or rests have been in use for a long time, we have found that the one we describe is the most effective in eliminating abdominal pressure during surgery. The pillow can also be used for hip surgery, the patient placed upon it on his side. We have found that, used in this manner, the pillow effectively stabilizes the patient.

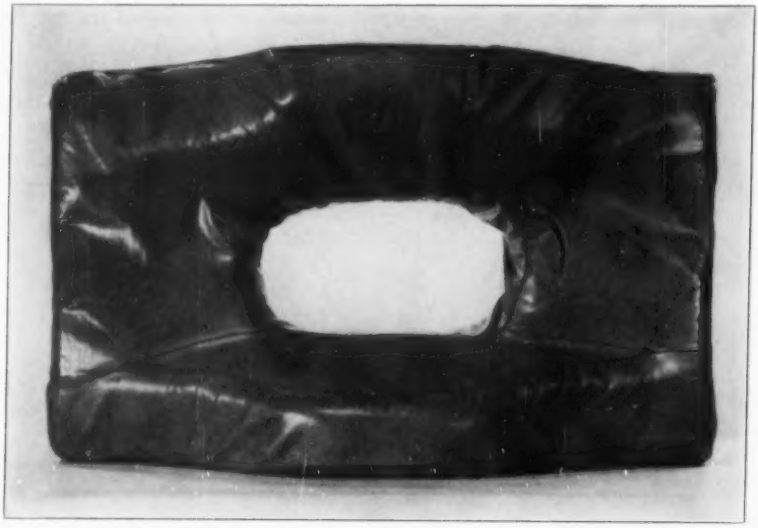

FIG. 1

FIG. 2

The pillow is fashioned from a large block of foam rubber of medium firmness and is covered with vinyl plastic. It is twenty-eight inches long and sixteen and one-half inches wide. The ends are four and one-half inches thick. The sides are nine inches high, sloping inward to four and one-half inches at the rim of the inner opening. The opening is six and one-half inches wide and twelve inches long (Fig. 1).

The result is a flexible but firm trough with a large central opening. The patient is placed upon it with the opening under his abdomen, permitting the abdomen to remain relaxed and free from pressure during the operation (Fig. 2).

When properly positioned at the break of the operating table, the pillow permits flexion and extension of the spine during surgery by means of the controls of the operating table.

NOTE: We gratefully acknowledge the help of Mrs. Norma Noe, R.N., in the development of this pillow.

A Device for the Treatment of Torticollis in Infants

BY VICENTE SGANDURRA, M.D., SALT LAKE CITY, UTAH

From the Primary Children's Hospital, Salt Lake City

This device was developed as an improvement on other similar devices to maintain an infant's head in a position necessary for the overcorrection of wry-neck deformity. The methods used in the past admittedly have been ineffective or cumbersome. During the first two months of life, there is no difficulty in keeping a baby lying on its back, and

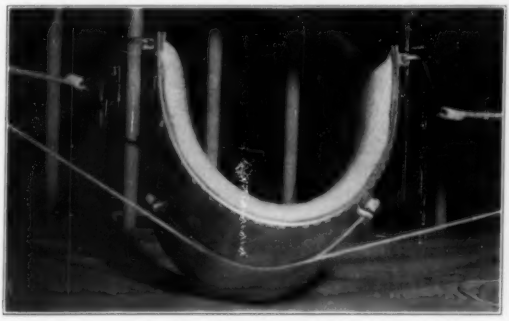

FIG. 1

The head turner, showing details of its construction.

FIG. 2

The head turner in use.

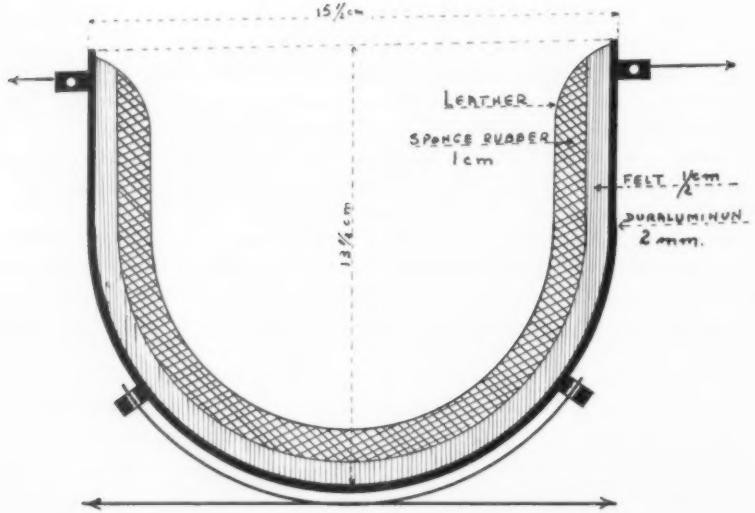

FIG. 3

it is during this period that the apparatus is the most useful (Figs. 1 and 2). Older infants may need a small, restraining jacket to keep them from turning over.

The device described here has been used in the treatment of two infants. Both children had congenital dislocation of the hips as well as wry-neck deformities. They were both two months old. One infant was so frail and listless that she seldom moved more than her hands. This child's condition prompted the development of the head turner. The patient was kept in it for four months. No surgery was done. A complete correction of the wry-neck deformity was obtained. Surgery was performed on the other infant, and although he was a normally active child, he was successfully held in the necessary overcorrected position for two months postoperatively, with good results. Both babies were turned to the prone position at regular intervals and during these periods, of course, the head turner was not used.

The apparatus is constructed from a piece of duraluminum, bent into a U shape, heavily padded with a layer of felt and a layer of sponge rubber and fitted with eyelets on each side, above and below. It is bent to fit the infant's head closely enough to prevent turning of the head in the apparatus, but not snug enough to chafe the child's head or to restrict circulation. The U-shaped piece of duraluminum is thirteen and a half centimeters deep and fifteen and a half centimeters wide. Small cords thread through the eyelets and fasten to the crib. Any desired degree of correction can be obtained by the adjustment of the cords (Fig. 3).

The child should not be left in the head turner continuously but should be turned occasionally to the prone position. The use of the device is limited to infants under four months of age.

This method appears to be superior to the usual intermittent stretchings since the corrective force can be controlled and applied continuously over a period of time. The two babies on whom it has been successfully used had severe torticollis with multiple deformities. In uncomplicated cases it is possible that the head turner may be effective in a shorter period of time than was necessary with our two patients. The appliance has not been used for wry-neck due to vertebral deformities, and, in such a case, it is doubtful that it would constitute more than a palliative measure.

Proceedings

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS SCIENTIFIC SESSIONS

Saturday, January 26, 1957

The Three-Dimensional Anatomy of Haversian Systems. Dr. William H. Harris [1] and Dr. Jonathan Cohen [2] reported a study in which serial-section reconstructions had been made of femoral diaphyses of adult dogs. The patterns of the Haversian systems (or osteons) had been examined with special regard to their longitudinal extent, vascular communication, and relationship to the periosteum and endosteum, and models of several systems had been made in order to illustrate their configuration and their interrelations in three dimensions.

Dr. William T. Green, President, and his guest of honor Mr. Thomas King of Melbourne, Australia.

It was found that the principal orientation of the canals and their respective lamellar systems is diagonal to the axis of the femur. It appeared that the systems extend from the vicinity of the periosteal circumferential lamellae distally to the endosteum through an excursion about one centimeter long in the femoral shaft; because of the frequent branching and anastomosing of the systems, however, delineation of the extent of a single system was difficult and depended on the definition proposed. Haversian systems were found to interdigitate and to vary greatly in area and shape from section to section. Single systems often appeared twisted or spiral in configuration. The Volkmann's canals, which were numerous and had no apparent relationship to the shape, branching, or longitudinal character of the Haversian systems, were predominantly transverse and short and were never surrounded by concentric lamellae. It was found that some osteons end or begin blindly as conical structures imbedded in interstitial lamellae, but that they never end or begin in intact osteons. This finding was thought to be evidence that some new Haversian systems form as a result of burrowing and concomitant deposition of bone in excavated areas. In the region of the external circumferential lamellae, another method of the formation of osteons was observed. In this region, discontinuous segments of some of the previously existing longitudinal vessels acquired concentric lamellar investment, while the other segments

[1] 300 Longwood Avenue, Boston, Massachusetts.
[2] 300 Longwood Avenue, Boston, Massachusetts.

remained as uninvested canals in the external circumferential lamellae. Progression of the process could lead to the formation of a Haversian system.

Compression Studies on Bone in Tissue Culture. Dr. George G. Rose [3] and Dr. Thomas O. Shindler [4] had studied the effect of pressure on the emigration of cells obtained by culture of avian embryonic bone. This study was conducted in a specially designed chamber by means of phase-contrast and interference-color-contrast techniques, microscopic examination, and time-lapse cinematography. In three of the experiments in this study the cultures on which pressure had been applied showed the greatest degree of emigration, and in three the control cultures showed the greatest degree of emigration. When the results were averaged, it was found that there was less than one-tenth of a point difference between the two groups, which included 208 specimens of bone. Thus it was apparent that the cells grew vigorously under positive pressure, but it was not determined that conversely positive pressure exerted a favorable influence on cell growth.

Histochemistry of Aging Periosteum. Dr. Edgar A. Tonna [5] had made a histological study of periosteal tissue taken from rats ranging in age from a few days old to one year old. This study was made in order

Dr. William A. Rogers, President Green, and Adam Gruca, Warsaw, Poland.

to determine the activity of the alkaline and acid phosphatase, cytochrome oxidase, and succinic dehydrogenase. The activity of the phosphatases in the sections remained at a high level throughout the age range, but the activity of the two respiratory enzymes diminished appreciably after the fifth week and was hardly demonstrable in the older animals. These changes were not further analysed quantitatively and were attributed to the aging process. The studies provided information which may be used as preliminary control data in future studies on the effects of injury on the reactions of periosteum.

The Effect of Total-Body Irradiation on Bone Transplants in Parabiotic Animals. Dr. W. F. Enneking [6] and Mr. Avrum Gratch [7] presented a preliminary report of a study which had involved 373 pairs of parabiotic rats. Death from parabiotic intoxication had occurred in ninety-nine pairs, while death from other causes had occurred prior to completion of the experiment in 142 pairs. Thirty-seven pairs had survived operative union, irradiation, and bone transplantation and were available for study. Each pair consisted of one rat totally irradiated before and after parabiosis (200 roentgens per week) and one non-

(*Continued on page 686*)

[3] 1402 Outer Belt Drive, Houston 25, Texas.
[4] 1206 Hermann Professional Building, Houston 25, Texas.
[5] 535 East 70th Street, New York 21, N. Y.
[6] The University of Mississippi Medical Center, Jackson, Mississippi.
[7] 950 East 59th Street, Chicago, Illinois.

Orthopaedic Surgery, Yesterday and Tomorrow *

BY WILLIAM T. GREEN, M.D., BOSTON, MASSACHUSETTS

In this twenty-fifth year in the life of The American Academy of Orthopaedic Surgeons, it seems appropriate to review the accomplishments of orthopaedic surgery during this period, to analyze our strength and weaknesses, and to consider hopefully our future.

In choosing such a subject I follow a common pattern of your Presidents. Most of us feel compelled to share our wisdom on this subject with you. I recognize that Presidential Addresses were designed for Presidents and not for audiences, so I humbly beg your indulgence.

During this twenty-five years, The Academy has grown from a struggling infant, through its fledgling and adolescent periods, to a well rounded maturity. It is today an organization of 2,280 orthopaedic surgeons, including our novitiates of yesterday. The Academy has become a moving force in medicine and in all areas of orthopaedic surgery. Its meetings bow to those of no other organization in any field. It has assumed a large influence in postgraduate education and in the standards of orthopaedic surgery, not only through its meetings, with their scientific programs, exhibits, and instructional courses, but also through many of its other projects and activities. The Academy is more than a society which holds annual meetings, important as they are; it is a busy organization the year around.

Particularly impressive is the work accomplished by the many committees of The Academy and the labors and devoted service of those who serve on such committees. Many individuals give much more than their fair share and it would seem that in our large organization such service should be more widely distributed. This is true, but it is not as easy to accomplish as might appear at first glance. If one individual appears on committees more than another, one may assume that it is because he is known to be dependable, his decisions are respected, he works, and he gets his job done. Such a person must have many attributes; but, beyond everything else, he must labor. Some of us who may like the idea of a position on a committee would not assume the responsibilities which this entails. Yet a large number of our membership would. It is safe to say that for any job now being carried out by a member of our Academy there are ten others for each position who would do the job as well. Some technique of developing greater participation of our members is needed. The increase in the number of Regional Committees and a pattern of succession in these Regional Committees which is now being established may help to foster this. It would appear that as our organization increases in size, the activities and the duties of these Regional Committees should be expanded.

PLACE OF ORTHOPAEDIC SURGERY TODAY

What is this orthopaedic surgery which we propose to discuss? What is its place in the cross section of clinical medicine? What proportion of medical practice, for example, falls into the area of neuromusculoskeletal disease or, as it is commonly expressed, the field embraced by conditions affecting the skeleton and the organs of movement.

In this age of wars, automobile accidents and, despite these, of increasing longevity, conditions affecting the skeleton and the organs of movement assume an increasing importance. The fact that injuries of this distribution form a major portion of trauma in

* Presidential Address read at The Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1957.

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wartime is well recognized. In the report *Orthopedic Surgery in the European Theater of Operations* edited by Mather Cleveland for the series *Surgery in World War II*, it was recorded that involvement of bones and joints occurred in 40 per cent of battle injuries and 36 per cent of non-battle injuries. For example, in the 802 Hospital Center, consisting of nineteen hospitals of which thirteen were general hospitals and six were station hospitals, 40 per cent of the 18,000 beds were assigned to orthopaedic surgical patients. In the Third Army, over a six-month period, 67 per cent of battle casualties involved the extremities. Wounds of the extremities made up about 70 per cent of the case load at evacuation hospitals. About one-half of these were compound injuries. In the Korean War, it was estimated by Cleveland that as many as 90 per cent of wounds affected the extremities. This index of casualties becomes more impressive when one considers the relative time and medical effort needed for the rehabilitation of skeletal injuries as compared with that required by injuries in other parts of the body.

The report of the experiences of the Navy in World War II gave a similarly high rate of injuries involving the motor system. Of 11,500,000 sick-days from injuries for non-battle cause, 7,000,000 were for injuries of the motor system; and of the over 144,000 combat injuries, 47 per cent were orthopaedic in nature.

In peacetime the figures are still impressive. In the figures for the Armed Services in peacetime furnished by the Surgeon General of the Army, Major General Hayes, and by the Surgeon General of the Navy, Rear Admiral Hogan, the proportion of medical needs affecting this area is considerable. In the Army, in 1953 and 1954, 28 per cent of the time lost from duty arose from injuries involving the skeleton and organs of movement, of which 13 per cent was from trauma and 15 per cent from disease. Just over 10 per cent of admissions to hospitals during that period were in this category. Almost identical figures represent the naval experience; for example, in 1955 it was found that 23.7 per cent of sick-days arose from orthopaedic disabilities.

Civilian experiences are less precisely recorded. Recently in the State of Washington in a well controlled survey, a study was made by Standish and others to determine why a patient visits a doctor. Over 73,000 visits were analyzed. As we reviewed their basic data, it was calculated that 17 per cent of all visits in which there were complaints were for conditions affecting the neuromusculoskeletal system. If one excluded visits for respiratory conditions and health examinations, the figure was 20 per cent. In the list of reasons for consulting a physician, accidents rated third in numbers exceeded only by health supervision which included prenatal care and by respiratory involvements.

In two of the Boston hospitals associated with the Harvard Medical School, sample studies were made of the percentage of admissions and hospital days that were orthopaedic. In The Children's Hospital, Boston, a general hospital for children, in the years 1955 and 1956, 22 per cent of the out-patient visits were for orthopaedic treatment, 12.6 per cent of patients admitted were for orthopaedic treatment, and 27.5 per cent of hospital days were orthopaedic. In the Peter Bent Brigham, an adult hospital which does not emphasize orthopaedic surgery, admissions in an orthopaedic category made up 16 per cent of surgical admissions and 8.4 per cent of all admissions. In total hospital days, orthopaedic admissions made up 18 per cent of surgical days and 10 per cent of the total for all services.

A further index of the volume of the field with which orthopaedic surgery is concerned is constructed by considering the number and types of accidents. By the figures of the National Safety Council, there were 9,350,000 accidental injuries in 1955. Unfortunately, only those which occurred at work were classified as to the location of the injury. Of the 1,900,000 accidents so classified, just over 1,000,000 involved the extremities. Further data regarding the types of accidents which occur in civilian life are provided by a sample study made in Baltimore, for the period 1938 to 1943, as reported by Collins and others. Fractures and joint injuries comprised 29.6 per cent of all accidents and 36.7

per cent of disabling injuries. Fractures and joint injuries, furthermore, were the cause of 57 per cent of total days of hospital and house confinement caused by accidents. Further information regarding skeletal injuries is provided by a recent survey fostered by the American Medical Association and the American Hospital Association in which the number of fractures treated during 1954 in the 6,970 approved hospitals is recorded by Dickinson. The total number of fractures treated in these hospitals in 1954 was 700,000. This was 9 per cent of all surgical patients admitted.

By all evidence, the diseases and abnormalities of the skeletal system and the organs of movement form a sizeable proportion of the ills of man. It is in this very large field that we specialize — here lies our responsibility.

It is true that many of the patients with diseases and abnormalities of the skeletal system and organs of movement are not cared for by orthopaedic surgeons; nor should they all be. Much of the care in many of these conditions is appropriately provided by general practitioners and others. Yet, the orthopaedic surgeon must be responsible for establishing standards of care and for leading the way. He must be responsible for research, for developing new methods, and for teaching. He must be available for the treatment of those conditions which require his specialized skill. The big thing is that patients with conditions affecting the skeleton and the organs of movement must receive the best care. As we survey the magnitude of this field, two basic facts are obvious: (1) there are not enough orthopaedic surgeons to take care of the patients that should be taken care of by orthopaedic surgeons; and (2) in view of the fact that conditions affecting the neuromusculoskeletal system form a large segment of medical practice, more training in this field is necessary as a part of undergraduate medical education and in postgraduate training.

War and modern living have made this field larger. Have we, as orthopaedic surgeons, met the responsibility in this large segment of medicine in the past twenty-five years? Let us consider some of the happenings in our specialty and in the field of neuromusculoskeletal disease during this period. Advances are often the product of the activities of many. The assessment of proper individual credit for contributions may be difficult. It seems appropriate, therefore, in speaking of accomplishments, that we avoid the naming of individuals, lest we omit the names of those who have contributed more to a particular field than those who are named.

ACCOMPLISHMENTS IN ORTHOPAEDIC SURGERY

Bone-grafting and bone banks: One of the major gains in surgery in this period has been in bone-grafting and its related phenomena. Extensive research has clarified the biological performance of transplants and their uses in clinical medicine. It was during this period that the use of homogenous bone stored at low freezing temperatures was found to be clinically feasible. Bone banks have become commonplace. These advances in the transplantation of bone and bone storage have permitted major developments in reconstructive surgery and in various other phases of our specialty. Furthermore, the experiences of bone banks have contributed to the general use and storage, at low temperatures, of grafts other than bone.

Material and metals: During this period, much research has gone into the development of materials and metals with the object of developing those which are relatively biologically inert. With the use of such metals and materials, great strides have been made in various areas, whether in their use for fixation, for substitution of structures, or for purposes of creating motion. Special efforts are now in progress to establish and to control better standards for materials which are for biological use.

Arthroplasty and joints: Surgical treatment of joints has made progress in many aspects during this period. Débridement of joints and more useful synovectomies have become effective procedures in the salvage of many joints which in the past would have been destroyed. Although arthroplasty is a development of the past, arthroplasty of the

hip has become a workable procedure only during this period. The development of Vitallium molds and of internal prostheses in such arthroplasties has been a major contribution.

Fractures: Treatment of fractures has made great strides. The main advance has been in the effective use of open surgical procedures. With the improvements in metals and the development of those which show a relative inertness, internal fixation has been vastly improved and more dependable procedures have been evolved. Skeletal fixation with plates, screws and nails and, more recently, intramedullary fixation as well as the use of bone grafts have revolutionized the treatment of fractures in these twenty-five years. This has been called "the metallurgic age" of orthopaedic surgery; yet in spite of all the excesses and misuse of metals, the gains in the care of fractures have been tremendous.

Back pain: One of the major causes of back pain, the diseased intervertebral disc, has become a recognized entity. It is difficult to believe that this syndrome which has become so commonplace in our differential diagnosis and in our treatment has only been a real part of clinical medicine in these twenty-five years. Sacro-iliac strain and sacro-iliac fusion have silently crept away.

Skeletal growth: The knowledge regarding skeletal growth and the correction of discrepancies of length has made great progress in these twenty-five years. Prior to this time the way of correcting discrepancy in length was that of limb lengthening or limb shortening. No method of effectively modifying growth of the epiphysis was available. During this period effective techniques of epiphyseal arrest by epiphyseodesis and by stapling have been developed, along with methods of predicting growth which define the time of such arrests and make them feasible. All this has made great difference in the treatment of crippling disease and in correcting discrepancies in length and deformities in the growing child. Furthermore, many other approaches to the problems of growth are being explored, such as techniques of stimulating growth, as well as investigation into the causes of disturbances of growth and their prevention under varying circumstances. Much of the research in the field of growth, even establishing the norms of skeletal growth in various areas, is being done by orthopaedists.

Scoliosis: Scoliosis in many of its aspects still remains a problem; yet the improvement in treatment during these twenty-five years has been noteworthy. It is during this time that insight has been developed regarding the areas of fusion in surgical treatment. Better techniques of correcting deformity prior to fusion have been evolved, as have better methods of postoperative immobilization and care. The result has been most salutary in a very deforming condition.

Infections: The treatment of infections of bones and joints has made spectacular gains during this period. This is true both of infections due to a pyogenic organism and those due to tuberculosis. It was not too long ago that osteomyelitis had a 20 to 25 per cent mortality rate. The adage "once osteomyelitis always osteomyelitis" was not too far from the truth. Effective chemotherapy, combined with sound surgical principles, has changed all this. The mortality is practically nil, and except in rare instances, the morbidity is inconsequential. Even before chemotherapy, great advances had been made in the surgical treatment of bone and joint tuberculosis; but with the advent of chemotherapy, dramatic changes have occurred. In synovial tuberculosis with effective early chemotherapy and proper protection, joints may be saved as mobile full-functioning structures. In many extensive lesions requiring intervention, surgery may be performed early and effectively. Tuberculosis of bones and joints is now a different disease. The mortality rate has been tremendously reduced. The disease process is arrested and controlled, and the bone lesions respond in a striking way.

Localized lesions of bone: Many of the pathological processes of bone which were not recognized twenty-five years ago or about which little was known are gradually yielding to the pressure of investigation. Eosinophilic granuloma, for example, has been differentiated, and its pathological characteristics and therapy have been clearly defined.

This is also true of osteoid osteoma. In many of the various space-occupying lesions of bone which provoke a cystic appearance in the roentgenogram, and even in malignant tumors, many gains have been accomplished in the form of improved classifications and better techniques of treatment.

Tendon transplantation: Tendon transplantation, tendon transfers, and free tendon grafts were all accepted procedures twenty-five years ago, but the refinements in techniques, the development of particular procedures, the improvements in methods of postoperative supervision and training have all contributed toward revolutionizing their effectiveness in surgical rehabilitation, in the foot, the hand, and other areas.

Reconstruction and rehabilitation: The practical application of many of the diverse advances in clinical techniques and experiences have produced major gains in the whole field of reconstruction and rehabilitation. Major procedures, both in the child and in the adult, which could not have been foreseen twenty-five years ago have become commonplace. Improvements in fluid replacement and in anaesthesia have contributed to those gains, but even more the gains have been the result of the evolution of surgical techniques. The combination of such procedures as transplantation of bone, tendon transplantation, the use of metals or other inert materials, whether for fixation or to facilitate motion, together with sound imaginative concepts, have made for remarkable progress in the whole reconstructive field.

With this have come increasing improvements in physical therapy, in functional training, and in the various phases of rehabilitation. It is well to remember that orthopaedic surgeons were those responsible for the birth and development of physical therapy, of physical medicine, and of rehabilitation.

Other bone research: During this period many of the biological and metabolic performances of bone have left the realm of hypotheses and achieved the status of fact. These gains have arisen from the assemblage, piece by piece, of the work of many investigators. Radioactive materials have been of great assistance not only in evaluating previous work, but in expanding experimental investigations in this whole sphere. Many pathological processes and basic normal mechanisms have come within our understanding during this period. Tissue-culture techniques; increasing attention to histochemical and biochemical methods; more animal experimentation; modifications of bone metabolism and growth by various experimental methods, including the effect of the aminonitriles; intensified studies of neuromuscular activity, of muscles and the laws of muscle contracture; all of these have contributed to orthopaedic surgery.

THE FUTURE OF ORTHOPAEDIC SURGERY

We have accomplished much and yet there is much to accomplish. It is a common practice for our Presidents to exhort us about the need for increased research. Guy Caldwell, in 1931, Francis McKeever, in 1953, and Al Shands, in 1954, have discussed this problem and made pertinent suggestions. McKeever took a frankly saturnine view of basic research in orthopaedic surgery. The Rich Report spoke of "the paucity of research" and included some other unflattering comments. The idea that there is a dearth of orthopaedic research has been so well publicized by orthopaedic surgery itself that it has become a subject of general discussion or even gossip among medical men at all levels.

I do not feel pessimistic about our accomplishments. On the contrary I am impressed that we have accomplished much under difficult circumstances. Our basic research has been creditable and our progress in clinical medicine and clinical research in these twenty-five years has been outstanding.

Investigative activity has expanded greatly in the postwar period. Many things have influenced this expansion. The activities of the Orthopaedic Research Society and of the Orthopaedic Research and Education Foundation have been stimulating factors and should continue to be.

Yet, as we consider the future of orthopaedic surgery and its responsibilities, increased research has a top priority. I would list three needs beyond the rest: (1) we need more research and experimental investigation, (2) we need more men and more top-flight men in orthopaedic surgery, and (3) we need to improve undergraduate teaching and the position of orthopaedic surgery in our medical schools. These three areas of need are basically so interrelated that they should be discussed together.

If we grant that we have made many contributions to basic research, why have we not contributed more? There are many possible factors. Could it be due to the type of individual who is in orthopaedic surgery? The men practising our specialty form a cross-sectional representation of the attributes and characteristics of all men in medicine; yet a considerable percentage are likely to be individuals of intense practicality who are impressed by the precision and mechanical factors represented in certain phases of the specialty. Individuals with these interests may show somewhat less interest in basic research than individuals with certain other attributes. Furthermore, clinical investigation and the need for clinical and technical gains have made overwhelming demands upon our interest and upon our time. Work in this area, it should be added, has produced many striking advances in clinical medicine which after all is the objective of all medicine.

A definite factor inhibiting research in all its aspects is the great shortage of orthopaedic surgeons and the great demand for them to do clinical orthopaedics. Even those who are interested in research and intend to stay in academic areas are likely to succumb to the pressures and go into practice, soon to be so busy that they do little else. A crowded market in orthopaedic surgery such as exists in general surgery would change this factor immediately.

Many pertinent questions can be asked. Is it that our young men who would be interested in research in whatever field they enter are not attracted to orthopaedic surgery? Is the field infertile for research activity? It would not seem so. One of the great attractions in orthopaedic surgery is the tremendous variety of diseases and abnormalities that involve the musculoskeletal system and the testing character of its many problems. There are more types of demonstrable lesions in bone, for example, than in any other tissue, and with few exceptions they represent a challenge as to etiology, and, in many, a challenge as to treatment. Orthopaedic surgery should attract its share of men interested in research, and it should attract more men in medicine; yet I do not believe that we do get our fair share of medical graduates off the top of the heap. It is worthy of comment that interest in orthopaedic surgery is rarely generated in medical school, but rather in graduate training, often late in graduate training. It would appear that this arises, in large part, from the limited exposure of the student to orthopaedic surgery in medical school.

What about the environment for orthopaedic research — is it good? The major part of research and its stimulation arises in medical schools. Do we in orthopaedic surgery have stable well supported departments with adequate laboratories and a sufficient research budget? Do we have support for full-time men in our departments as well as support for younger men? Are the senior men in orthopaedic surgery in our schools working in such an environment and in turn stimulating younger men in this activity?

For some additional insight into this and other influences affecting orthopaedic surgery, it seemed wise to consider further the place of orthopaedic surgery in our medical schools. As a part of this consideration, we sent out brief questionnaires to the deans of schools and to the heads of departments of orthopaedic surgery, insofar as their listing was available.

The questionnaire sent to the heads of orthopaedic departments was primarily concerned with the hours of teaching in orthopaedic surgery, the hours in general surgery, and the hours in all surgery. The figure for all surgery included general surgery, the individual surgical specialties, and orthopaedics. Sixty-five questionnaires were sent out. We re-

ceived replies from forty-nine schools, of which thirty replies gave information on all questions and forty-two could be used for certain parts of the study.

The average number of hours of orthopaedic teaching for the full four years in the forty-two schools was 126. There was a great difference in the assigned time in the various schools. In the ten schools devoting the least time to orthopaedics, the average was fifty-six hours in the four years. In contrast to this, in the ten schools devoting the most time to orthopaedics, the average was 232 hours in the four years.

In the thirty-two schools from which figures were available, the time devoted to orthopaedic teaching was 14 per cent of the teaching time for all surgery. In 25 per cent of the schools orthopaedics received only 7 per cent of the total surgical teaching time. At the opposite end of the pole were three schools devoting 27 per cent of the total surgical teaching time to orthopaedics.

Inquiry was made as to the types of teaching. In the questionnaire teaching was classified on the basis of whole-class and of small-group teaching. Whole-class teaching was subdivided into lectures and clinical demonstration. Small-group teaching was subdivided into clinical demonstration and clinical experience. The latter term was intended to cover both out-patient activities and clinical clerkships on the wards.

In the forty-two schools, the whole-class type of exercise averaged thirty-seven hours, of which twenty-two were lectures and fifteen were clinical demonstration. Teaching in small groups made up eighty-seven hours, of which clinical demonstration was thirty-seven hours and clinical experience made up fifty hours. These figures reveal that the pattern of small-group teaching is receiving increasing emphasis, which is as it should be.

It is impressive that orthopaedic surgery has an average of only three hours of teaching prior to the third year. Teaching in general surgery in this period averaged twenty-five hours. It is appreciated that during this time general surgery is concerned with basic principles which are pertinent to all surgery. This is an important period of exposure; orthopaedic surgery should participate to a greater extent at this time in the teaching of basic surgical principles and the basic principles affecting the skeleton and the organs of movement.

As we reviewed the teaching hours and the assignments of types of teaching in the various years, it was apparent that in a good many schools, the students were receiving too little teaching to allow any reasonable approach to the subject; yet, by the same standards, some schools allotted a very satisfactory number of hours for orthopaedic teaching. In most schools, however, the neuromusculoskeletal system was not in the main channel of teaching in the first years and was used most sparingly to illustrate basic biological phenomena. Furthermore, many areas in basic science which are important to understanding in this field were slighted. The result was that the student did not to a sufficient degree in his early education become acquainted with this system nor with its teachers.

Certainly, in the preclinical years teaching must provide the basic blocks of understanding upon which orthopaedic surgery and the neuromusculoskeletal system and its abnormalities rest. In the first two years the student should obtain an understanding of the fundamental phenomena which are pertinent to this system. To build on this foundation he must be given enough instruction and clinical experience in the third and fourth years to develop that knowledge and judgment of conditions of the skeleton and the organs of movement which all graduates of medicine should have. The neuromusculoskeletal system is a complex system with many ramifications and the time allotted to its teaching must be considerable if any reasonable understanding is to be developed.

Orthopaedic surgery, by all the measurements that we can make, is a major field of medicine. In this age of wars and accidents all physicians need to develop a better understanding of the musculoskeletal system and its problems. Teaching in orthopaedic surgery

must recognize this and it should receive the emphasis which its position in the total medical picture warrants.

The question arises as to how many hours should be assigned to orthopaedic surgery. The details of teaching and teaching hours would necessarily vary with the situation in the particular school. Even under the most effective instruction, and assuming that there has been a good background for orthopaedic surgery provided by teaching in the basic sciences, 160 clock hours seems to be the minimum that would permit a reasonable instruction in this field; 220 clock hours might be a reasonable amount to recommend.

As we considered from where these hours might come, we have been impressed that they should not necessarily all come from surgery but rather that a greater portion of hours should be developed after considering the whole curriculum. Surgery in other areas has none too many hours. Certainly much that orthopaedics contributes to the basic education of a medical student comes under the general classification of medicine, as well as surgery. A good part of the practice in orthopaedics is medical, and much that the general man in medicine should know about our field is in a medical category. It should be recognized that orthopaedic surgery is made up of both medical and surgical components. The percentage of teaching time assigned to orthopaedics should not be related just to surgery but should be evaluated in relation to all clinical teaching.

The questionnaire to the deans of medical schools contained, as its major interest, questions regarding the budget allocated to orthopaedic surgery. In order to avoid a direct question as to the amounts in the budget, which might be construed as impertinent, we asked that the budget for orthopaedic surgery and for general surgery be expressed as a percentage of the total surgical budget.

Of the eighty-six undergraduate schools to which questionnaires were sent, sixty replied, of which fifty-four gave material that could be analyzed.

The average budget for orthopaedic surgery in all these was 9.6 per cent of the total budget in surgery. As we divided the schools into percentiles on the basis of the amount of orthopaedic budget, certain interesting comparisons arose. In the 25 per cent with the lowest budget, the average budgeted amount for orthopaedics was 3.8 per cent of the total surgical budget. If we took the average of the fifty schools falling in the lowest half of budgeted amounts, the average was only 5 per cent. By contrast, in the schools falling in the 25 per cent with the highest budget orthopaedics received 18 per cent of the total surgical budget. These considerations emphasize the very limited support in many of our schools. Even in the schools with the greatest amount of support, orthopaedic surgery had a relatively modest percentage of the total amount.

In the forty-two schools in which the budget was differentiated as to orthopaedic surgery, general surgery, and the specialties, the average budget for orthopaedic surgery was 9.7 per cent of the total surgical budget and the general surgical budget was 51 per cent of the total with a ratio between the two of approximately 5 to 1.

In seven schools the budget for orthopaedic surgery was recorded as zero and that for general surgery was 100 per cent. In two of these the budget was combined and there was no way to differentiate the funds for orthopaedics, but the other five seemed to express the actual budgetary state of the orthopaedic department or division; namely, no funds were provided. The considerable number in which the budget was undifferentiated and recorded as all general surgery was significant in itself, in that it indicated that the budget was not under the control of orthopaedic surgery.

The impressive information from these questionnaires was the great variation in support and the limited budget that is provided for orthopaedics in a large proportion of our schools.

Certainly the figures indicate that orthopaedic surgery receives limited financial support whether expressed in terms of the percentage of support given to all of surgery or in specific relation to general surgery. In many schools it is obvious that if the teachers

of orthopaedic surgery and the departments of orthopaedic surgery depend primarily on the budget provided by the school that they could not exist. In the majority of our schools the teachers in departments of orthopaedic surgery are men who must support themselves, carry on their teaching in the medical school in addition, and often provide a great part of the support for their departments.

Under these circumstances, one might expect that the research activity in such a department might be limited. If research is to prosper, orthopaedic departments need financial support, hard money, not support of transient type, but sufficient guaranteed support over the years to give stability to the department and allow its activities to develop at a dependable level. Financial support, really adequate financial support, is needed not only for the heads of departments but for the other individuals in the department and for an adequate budget to finance various teaching and research activities. Once such a set-up is developed and adequate laboratories are provided, together with a healthy clinical environment, we will not long need to be apprehensive about basic research in orthopaedic surgery. If enough long-term support is available to provide salaries for key personnel and other basic needs, expansion of activity comes easily from research grants for specific activities. One cannot be expected to build a department, however, on air and short-term grants alone.

In the eventual organization of departments, it is likely that many schools will find it desirable to have both a professor of clinical orthopaedic surgery and a parallel appointment of a research professor of orthopaedic surgery. In a specialty such as ours it would seem highly desirable that in this dual relation the professor of clinical orthopaedic surgery be under usual circumstances the ranking appointment. Such an arrangement should promote the strength in our departments for which we strive. Details of a department are peculiar to a school, but a certain number of full-time or classified full-time men in departments is important to the development of our field. It is well for us to add, however, that the nature of orthopaedic surgery as a specialty is such that the strength of a department must not be neglected clinically for the sake of basic research. Both aspects must be well represented in all departments. Part-time men in clinical orthopaedics are most valuable components of a teaching staff.

It is not only in its financial status that orthopaedic surgery strikes a weak note in our medical schools. As Leroy Abbott so well outlined in his 1947 Presidential Address to The American Orthopaedic Association, orthopaedic surgery has a minority position in our medical schools. As he reviewed the status of orthopaedic surgery, he stated that "my first recommendation for future development would be that orthopaedic surgery should secure full recognition in our medical schools as a major department of surgery with its own budget, the right to select members of its staff, control promotions, and be responsible only to the dean and the executive faculty." His remarks are just as pertinent today and should be repeated.

In only about one-third of the schools from which we have data is orthopaedic surgery recognized as a separate department. This of itself is not the most important consideration, although orthopaedic surgery has reached the position where it should have the status of a major independent department. One cannot be too critical, however, if orthopaedic surgery is classified as a division of surgery, if in such a classification, it is given autonomy, a separate budget, and an appropriate voice in basic decisions. The important thing is that orthopaedic surgery should participate in the fundamental councils and conclaves of the school. A separate department is, of course, ideal, and it is fitting. It does little good, however, to make orthopaedic surgery a separate department if you give it little funds and little or no representation in major decisions.

The present arrangement is a heritage of the past. One respects one's heritage. One of our primary objectives, however, must be to establish orthopaedic surgery as a major voice in our medical schools and to see that it is properly represented in their

organizational pattern. In the meantime, we must continue to demonstrate that this should be our rightful position. We must see that the dignity of orthopaedic surgery is recognized and respected in all schools.

As far as teaching is concerned, we must, for example, make maximum use of the hours which we now have. Those of us who have too few hours must be so convincing in our teaching activities that the need for increased teaching time in our field becomes obvious. As a group and individually we must develop better teaching techniques and aids so that our instruction will be more affective. We must push forward our research activities and our support of investigation despite the handicaps that exist. We must interest more students in orthopaedic surgery.

Our fundamental goal should be to see that orthopaedic departments in medical schools are placed on a sound budget and given the breadth which is important for the future development of our field. In many schools the solution will not be that of getting a larger share of the present budget, but rather that of getting new money. If adequate support can be developed, resistance to the change in the status of orthopaedic departments should be very little.

It must be appreciated that the limitation of research and hindrance to progress in orthopaedic surgery does not arise primarily from the lack of funds for specific research projects but from the dearth of well established units with basic long-term support which may be the nidus of such research activity. By expanding our departments in schools, we shall attain our three objectives. We shall establish productive bases of research, we shall be able to expand the instruction of all students, and we should increase the interest of the student in making orthopaedic surgery his future field of endeavor.

All of us in orthopaedic surgery must go to great effort to support these objectives in our schools. We should individually lend our influence, and we should both directly and indirectly strive to provide financial aid to the orthopaedic department of the school of our allegiance. Everyone has a school. Support of the Orthopaedic Research and Education Foundation is one way to assist. The Academy should take a renewed interest in undergraduate education, and in orthopaedic departments in our medical schools. This should be the concern of all. In certain other areas those of us in orthopaedic surgery might do some individual soul searching. We must face clearly as to whether in our busy days of practice we do not by-pass some of our fundamental responsibilities. Not so many years ago, for example, it was the orthopaedist who was the leader in many of the community projects concerned with medicine. It was the orthopaedist who stimulated the many hospital and community activities having to do with the handicapped and the crippled. It was the orthopaedist who fostered rehabilitation. It was the orthopaedists who made up the original advisory committee to the Children's Bureau in the planning and development of care of the crippled child. Yet, more recently, others seem to be carrying the torch in these fields. I am sure that many specialized individuals must work together in coordinated programs in these areas, and such programs require many of us. Is this relative inactivity of orthopaedic surgery a natural evolution, or is it the product of our own lethargy and a ducking of our responsibilities?

In fact, each one of us should assume tha he is in charge of public relations for all of orthopaedic surgery. Let us carry this assumption to our contacts with the individual patient, to our community and general medical activities. We should be the leaders in community projects affecting our field. We should participate in organizations and in programs which represent the interest of orthopaedic surgery whether medical organizations or lay organizations. It does no good to sit back and sneer.

So, too, must we ask ourselves about our part in the total field of neuromusculoskeletal disease. Many of us seem to concentrate on the actual performance of surgical procedures and show little interest in other than surgical aspects of our specialty. In our busy activities we tend to relegate many of our side responsibilities to others. If

the particular province of orthopaedic surgery is the skeletal system and the organs of movement, our specialty is, in reality, more medical than surgical. Is it a natural evolution that we should confine ourselves only to the surgical aspects? Is this sound? Our specialty is a functional one. Many of us who are older look upon the surgical procedure itself as but a step of a continuous program in an individual's care and rehabilitation.

Has orthopaedic surgery reached the crossroads where the field of orthopaedic surgery is more limited? If we are to be the technicians who come into a case when someone else decides it's time for surgery and then someone else gives postoperative care, will we in fact come to know less and less about less and less. Certainly if we make an analogy with general surgery, it would be an unusual state, if immediately after the surgery is over, the postoperative care were transferred to some other group. The postoperative care of many orthopaedic procedures may last not for a few days following the surgery, but for weeks, months and years. Will not our surgical judgments in such a functional specialty wither unless we follow the patient's musculoskeletal problems in detail. In no other field does the result depend so much on a continuous well conceived program.

At the same time we must use the help of others with special skills who can be of assistance in various phases of care. We must be careful not to sit in a self-satisfied reactionary state; yet we must always discriminate between progress and change.

Special interests in the field of orthopaedic surgery are appropriate. Localization and concentration of effort often lead to productive activity. Yet such localized endeavors must rest upon an all-comprehensive base. Certainly we must give our men in training the broad concepts of our total field and the skills for the total area. It is our belief that we are still in the period when we need to know more and more about more and more.

We are convinced that orthopaedic surgery in these twenty-five years has been worthy of its heritage but let us leave a record which our progeny will find hard to equal.

President Green with Prof. K. E. Kallio of Finland.

President Green presents Mr. Tom King with the Certificate of Honorary Membership.

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isogenous rat which had not been irradiated before parabiosis and which had been shielded from irradiation after parabiosis. In each rat a massive femoral homogenous transplant obtained from its partner had been inserted four weeks after parabiosis. Controls consisted of non-irradiated pairs. In 95 per cent of the control rats the transplants had been rejected (that is, evoked an inflammatory response which blocked repair), while in the experimental group in all but 5 per cent of the irradiated members the grafts had not been rejected. This indicated that total-body irradiation can block the mechanism which plays a role in the rejection of homogenous grafts. A surprising finding was that in 50 per cent of the non-irradiated members of the experimental pairs the grafts had not been rejected.

Repair of Bone-Transplant Fractures. Dr. Michael Bonfiglio [8] had studied by means of roentgenograms and histological sections the healing of autogenous and homogenous bone grafts which had been fractured and then implanted in defects made in the ulnae of rabbits. In the group in which autogenous grafts had been used, 72 per cent of eighteen fresh grafts, none of eleven frozen grafts, and 15 per cent of thirteen boiled grafts had healed. In contrast, in the group in which homogenous grafts had been used, 30 per cent of twenty-three fresh grafts, 8 per cent of twenty-six frozen grafts, and none of eight freeze-dried and nine merthiolate-preserved grafts had healed; furthermore, in this group, healing, when it had occurred, had been delayed for several weeks. The author concluded from this experimental study that fresh autogenous transplants are far superior to other types of bone transplants. Fresh homogenous grafts are the next best as regards osteogenic repair, but the author raised the possibility that the marked inflammatory incompatibility reaction which is caused by these grafts may be detrimental.

Epiphyseal Cartilage as an Endocrine Organ. Dr. Edwin G. Boyill, Jr.[9] had previously described the formation of abnormal fracture callus in growing guinea pigs given excessive doses of vitamin A. In the study reported in this paper, the author tested Wolbach's theory that the epiphyseal cartilage may be responsible for the remodelling process of bone growth. To determine this he used mice in which traumatic fractures of the femora had been made. In these mice he transplanted thin shavings of fresh frozen epiphyseal cartilage obtained from stillborn human foetuses. At the end of four and one-half weeks, he found that the fractured femora were uniformly healed in both the experimental and control animals.

Sunday, January 27, 1957

The Double-Pin Method in the Treatment of Fractures of the Tibia and Fibula. Dr. Milton J. Wilson [10], Dr. Jack Henry Mower [11], and Dr. Herbert G. Cohen [12] described a method of obtaining closed reduction of fractures of both bones of the leg by the use of skeletal traction. Incorporation of two Steinmann pins in the plaster cast maintains fixation in the postreduction period. This method may be employed to treat adult patients with unstable fractures or with fractures in which there is slipping. In a period of nineteen years, 893 patients had been treated in this manner. Of these, 285 had had open fractures.

The technique of insertion of the pins, method of reduction, and method of application of the cast were described in detail. The average time in plaster of the patients with closed fractures was fourteen weeks and six days, while the average time in plaster of the patients with open fractures was twenty-three weeks and three days. In the entire series there were only forty-nine instances of delayed union and sixteen instances of non-union, only five of which were in patients with closed fractures. Complications listed included superficial pin-tract infection in fifty-four patients, and there was generally reduction of motion in the subtalar joint of about 40 per cent. There were no instances of infection of bone at the pin site.

Metastatic Carcinoma of Big Toe. Dr. Gerald S. Ahern [13] and Dr. John F. Pilcher [14] presented the history of a patient in whom metastasis from carcinoma of the lung had been found in the distal phalanx of the great toe. This case was considered of interest for several reasons:

1. Mild symptoms of the metastatic lesion in the toe were present a year before the tumor of the lung was recognized. (Strang previously noted this phenomenon in relation to metastatic hand lesions from bronchogenic carcinoma.)

2. It is rare for metastasis to occur in the foot and even rarer for it to occur in the distal phalanx of the great toe, a site which has been reported as the location of such a lesion only once before.

3. The primary lesion was carcinoma of the lung. Lung carcinoma was the cause of the twelve hand metastases reported in the literature but of only two of the six pedal metastases previously reported.

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4. When metastases do appear in hands or feet, the presence of redness, pain, and swelling may make it appear that the lesion is due to some type of infection. Furthermore, metastatic tumors rarely involve a joint since the articular cartilage is not adversely affected by contiguity with tumor metastases.

The similarity of the clinical appearance of the toe in this case to that of an infected toe and the rareness of phalangeal metastases, particularly in the feet, delayed the correct diagnosis. The other bone metastases, which were located in the ipsilateral tibia and fibula and which were present but asymptomatic when the toe was amputated, subsequently became painful. The primary lung lesion, which was treated by x-ray therapy, was asymptomatic for one and one-half years before amputation of the toe and remained asymptomatic during the five months between the amputation and the time of writing.

In his discussion, DR. MURRAY COPELAND [15] pointed out that statistics show that bone metastases occur most commonly in those skeletal regions in which there is red rather than yellow, or fatty, marrow. This may be correlated with the fact that metastases to the foot or hand from tumors growing in the lungs are rare.

An Operation for Congenital Club-Hand. DR. RALPH T. LIDGE [16] presented a method of treatment for congenital club-hand associated with deficiency of the radius. Mention was made of ten cases in which bone surgery rather than extensive soft-tissue surgery was done. This bone surgery was designed to shift the deviated hand over the distal end of the ulna, and no preliminary soft-tissue stretching was done. The technique of the surgery was as follows. A dorsal subperiosteal dissection was carried out in order to expose the distal end of the ulna and the carpus. Following this a heavy Kirschner wire was used to make a hole through the medullary canal of the distal end of the ulna. After the wire was removed, osteotomy of the distal end of the ulna was done about two to five centimeters proximal to the epiphyseal line. A trough was then made in the carpal bones, the capitate and lunate being removed, and the heavy Kirschner wire was inserted through the medullary canal of the third metacarpal with the wrist and knuckle joints flexed. The segment of removed ulna was threaded on the wire, the hand adjusted, and the wire drilled into the ulna. In the two cases in which there was recurrence, an autogenous fascia lata graft was used to construct an ulnar carpal ligament. In the author's series seven patients, three with bilateral deformities, were treated by this method. The youngest patient was three years old and the oldest was twelve. The author reported that in two hands the results were excellent, in four they were good, and in two they were fair. The results in the remaining two hands were not determined because of insufficient follow-up. A motion picture of three of the patients was presented. In these patients the radial deviation persisted although there was some improvement. Hand deformity was usually present in the form of absent or incomplete segments, and the forearms were very short.

DR. ROBERT E. CARROLL [17], one of the discussors, compared this procedure to that described by Sayre. He objected to the removal of five centimeters of bone and to the interference with the distal epiphysis of the ulna in a child three and one-half years old.

DR. STERLING BUNNELL [18] reported that he uses a Z plasty in order to obtain relaxation of the skin and release of the deep soft tissues, thereby avoiding shortening of the bone. If osteotomy or shortening of the ulna is necessary, it may be done at a later age. Dr. Bunnell stated that he prefers the term *clinarthrosis* to *congenital club-hand*.

DR. DONALD E. STARR [19] recommended the use of soft-tissue stretching and splinting until the patient is ten years of age, at which time any indicated surgery may be done.

Monday, January 28, 1957

Criteria for Determining the Proper Level of Amputation in Occlusive Vascular Disease. DR. PATRICK J. KELLY [20] and DR. JOSEPH M. JANES [21] presented a report of 323 lower-extremity amputations performed upon patients with occlusive vascular disease. Four types of vascular disease were treated: (1) atherosclerosis obliterans, (2) atherosclerosis obliterans with diabetes, (3) thrombo-angiitis obliterans, and (4) miscellaneous types of embolic occlusions and peripheral aneurysms.

The authors stated that the indications for below-the-knee amputation in patients with these conditions are (1) slow onset of the disease process, (2) a palpable femoral pulse, (3) a functioning knee joint, (4) healthy skin extending at least as far as the mid-leg, (5) good capacity for bleeding in the region below the knee in which the amputation is to be done, (6) reasonable hope of rehabilitation of the patient, (7) the presence of thrombo-angiitis obliterans, and (8) poor results following amputation of the foot.

The indications for above-the-knee amputation listed by the authors were: (1) sudden arterial occlusion combined with weakness or absence of the femoral pulse, (2) sudden arterial occlusion combined with coolness of the skin above the mid-leg, (3) prolonged venous-filling time and evidence of severe ischaemia as revealed

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by elevation-dependency tests, and (4) embolic occlusion and gangrene of the leg caused by peripheral aneurysm.

The authors' experience indicated that the open-flap method of amputation was not significantly superior to the closed-flap method. Of the fifteen deaths which occurred after the operation in this series of 323 patients, four were in the group of 131 patients treated by below-the-knee amputation, ten were in the group of 114 patients treated by above-the-knee amputation, and one was in the group of seventy-eight patients treated by toe amputation. It thus appeared that there was a slightly higher mortality rate in the group with above-the-knee amputation.

Results of this study revealed that fifty-two of the 126 patients with below-the-knee amputations who were followed were using a prosthesis, while only eighteen of the 112 patients with above-the-knee amputations who were followed were using a prosthesis. The authors stated that in the determination of the level of amputation, the history and the physical findings are more important than the findings of special tests designed to demonstrate the adequacy of the circulation in the extremity.

Evaluation of an Operative Series of Lumbar-Disc Herniations. Dr. Frederick S. Webster [22] and Dr. Donald P. Smiley [23] presented data concerning 200 operations which had been performed upon patients with herniated lumbar discs two to ten years previously. Simple excision of the herniated disc had been done in 120 patients. In eighty of these patients (40 per cent) removal of the protruded disc had been followed by fusion.

The results were considered *excellent* if the patient had complete relief from both back and leg pain, had discarded all brace supports, and had returned to his previous occupation. They were considered *good* if there was relief from the original complaints and the patient returned to his previous occupation, but there was occasional backache or slight weakness and the patient sometimes needed support for the back. The results were considered *fair* if there was initial relief of symptoms, but the patient had intermittent aching and weakness of the back and occasional aching in the leg; and they were considered *poor* if there was no relief.

The authors reported that in 65 per cent of the patients in whom simple excision had been done the results were excellent or good. In the group in which fusion had been performed, 80 per cent of the patients had excellent or good results. Excellent results were obtained in 46 per cent of the patients treated by excision and fusion, but in only 24 per cent of those treated by simple excision. The authors stated that this apparent 15 to 20 per cent better result from fusion of the spine following removal of the disc had been recorded in other series.

The authors did not claim that all patients with herniated discs should be treated by fusion but said that each case should be judged individually. They stated that the results obtained depend primarily on the accuracy of the diagnosis and that myelography is definitely of value. Congenital anomalies or acquired conditions that lead to instability of the spinal column or to degeneration of intervertebral discs are the main indications for fusion. In general, inclusion of fusion in the disc operation provides a superior long-term result. Although in the authors' series pseudarthroses did occur, not all the patients with pseudarthroses required subsequent surgery or obtained a poor result. The authors recognized that the risk of pseudarthrosis is increased when long segments of the spine are fused and, for this reason, did not advocate fusion of more than two interspaces. They stated that disc lesions restricted to the lumbosacral level usually should be treated by fusion of this interspace only, but that ordinarily stabilization procedures should not be performed for protrusions of the third lumbar disc.

Posterolateral Bone-Grafting for Fusion of the Lumbar and Lumbosacral Spine. Dr. Melvin B. Watkins [24] reported his further experience with a technique of spine fusion in which autogenous iliac grafts are used to bridge the transverse processes, articular facets, and pedicles of the lumbar spine. Previously, in 1953, he had presented a detailed description of the operative technique and reported the preliminary results obtained in ten patients. The author listed as indications for the use of this method of fusion: (1) deficiencies of the posterior aspect of the spine due to congenital defects, (2) the need for spine fusion following wide laminectomy, (3) repeated failure of attempts to obtain spine fusion by the usual methods, and (4) the presence of tuberculosis involving the posterior elements.

At the time of writing thirty patients had been operated upon by means of this technique. In fifteen unilateral fusion had been done, and in fifteen bilateral fusion had been done. These patients had been followed for from eight months to eight years. Of the fifteen bilateral operations, fourteen had resulted in solid fusion; the result of the other operation had been questionable. Five of the unilateral fusions had failed initially, but in three of the patients repair had later been obtained. All complications were minor. In the first patients operated upon, the grafts had been fixed by means of screws, but in the last eleven patients internal fixation had not been used. In the postoperative routine followed at the time of writing, the patient was allowed to

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walk while wearing a brace three to four weeks after the operation; use of the brace was continued for six months.

Treatment of Certain Spine Disorders by Anterior Disc Removal and Interbody Fusion. Dr. George W. Smith [25] and Dr. Robert A. Robinson [26] reported a series of fourteen patients with disorders of the cervical spine who were treated by anterior disc removal and interbody fusion. The exact level at which the operation was to be performed was determined by physical examination, by plain roentgenograms made in the anteroposterior and right and left oblique projections, by lateral roentgenograms made with the neck in flexion and extension, and by anterolateral discograms. Myelograms were made of only two of the fourteen patients in whom there were questionable long-tract signs. At operation the anterior aspect of the vertebral bodies was exposed by an approach in which the carotid sheath was retracted laterally and the esophagus, trachea, and thyroid were retracted medially. After identification of the correct level by means of a roentgenogram made with the patient on the operating table, the anterior longitudinal ligament was incised, and the disc material and corresponding vertebral plates were removed. A block of autogenous iliac bone of appropriate size was countersunk into the space, over which the anterior longitudinal ligament was sutured. No postoperative immobilization was used unless pain developed, in which case a plaster cervical collar was used for from one to three months. Patients were allowed to get up on the first or second day after the operation. The patients ranged in age from twenty-five to fifty years. Five were men and nine were women. Eight had bilateral symptoms, and six had bilateral physical signs. In the total series, twenty-two spaces were operated on, from one to three spaces being fused in each patient. The fifth cervical space was fused eleven times and the sixth cervical space seven times. Of the remaining spaces the third and fourth cervical spaces were each fused once and the seventh cervical space was fused twice. Of the twenty-two spaces operated on, eighteen showed solid bone fusion and twenty-one showed no evidence of motion on bending roentgenograms made six months or more after the operation. Prior to the operation all the patients had had intractable pain unrelieved by conservative measures. All patients were followed for from fifteen to thirty-six months. The results were rated as *excellent* in nine patients in whom there was complete relief of symptoms, *good* in two in whom only minor symptoms remained, *fair* in two, and *poor* in one; in the latter patient extensive bilateral foraminotomies were subsequently performed with relief of pain. The complications encountered were Horner's syndrome in two patients (of one week's and six months' duration, respectively), transient paralysis of the vocal cords in two patients, transient tracheitis in one patient, and bleeding from a vertebral artery in one patient (this bleeding was controlled by gelfoam packing and caused no sequelae). In a patient operated upon after the completion of this series, perforation of the esophagus occurred; this was repaired, and six weeks later the spine procedure was done. There were no wound infections.

Spinal Osteotomy for Correction of Severe Flexion Deformity. Dr. Paul E. McMaster [27] presented a brief review of four cases of Marie-Strümpell disease of the spine. In these cases he had sucessfully corrected the flexion deformity by means of osteotomy. The only complication in this series was some loss of correction in one case. The author emphasized that in order to avoid serious complications the principles of technique as outlined in the original description of osteotomy must be adhered to. It was also pointed out that the indications for the use of this operation are limited, its chief value being in patients in whom the spine has been fused in a position of such severe flexion that the patient cannot see objects ahead. The author stated that the optimum site for osteotomy is in the lumbar spine below the second lumbar vertebra and that fusion should be carried out after the correction during the same operative session. In the four cases described recumbency was maintained for two months after the operation and some retentive apparatus was worn thereafter for periods of up to one year.

Fat Embolism. An Appraisal of the Problem. Dr. Leonard F. Peltier [28] presented the **Kappa Delta Award** winning essay. This essay brings into focus the current knowledge and the problems remaining to be solved in the field of fat embolism. Dr. Peltier combined his own extensive research with that of other leading investigators to summarize the basic pathological mechanisms which are encountered in fat embolism. The essential features of fat embolism are the presence of fat in the circulating blood in globules of sufficient size to obstruct arterioles and the presence of conditions in which there is (1) fragmentation of the parenchyma, (2) a previous vascular bed, or (3) a shift in local tissue pressure upsetting the hydraulic equilibrium. These features indicate that while bone trauma is the usual cause, soft-tissue trauma, hematogenous osteomyelitis, and rapid decompression from external pressure (such as may occur following deep-sea diving) may also be causitive factors.

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Once fat has entered the blood stream, fat embolism may manifest itself in one of two ways. In the early phase there is mechanical blocking of the pulmonary vessels by emboli, which results in acute ventricular failure on the right side. This is potentiated by shock. In the late phase there is a latent period during which chemical changes take place and neutral fat, under the influence of lipase, is converted into fatty acids. These acids attack the lung tissues, causing hemorrhage, oedema, and congestion, resulting in anoxia and death.

In prevention and treatment, gentle handling of the tissues and proper splinting of fractures reduces the amount of fat forced into the blood stream. The use of a tourniquet during elective operations minimizes the fat taken into the general circulation.

In the early mechanical phase, it is essential to prevent shock through gentle handling of the tissues, early transfusion and infusion, and rapid digitalization when early signs of heart failure are present.

The problem of treatment in the late phase is unsolved but the most likely avenues of approach are the use of lipase-suppression agents to prevent the conversion of neutral fats into fatty acids and the use of calcium ion infusions to convert the fatty acids into calcium soaps.

Experience Using Gastrocnemius Recession. Five-Year Report of Cases. DR. LUTHER M. STRAYER, JR.[29] presented a five-year case report of the gastrocnemius-recession operation which he had first described at the meeting of The American Academy of Orthopaedic Surgeons in 1950. He reviewed the neurological mechanisms which are involved in this anatomical approach to the problem of spastic equinus and cited the work of Silverskiold as an example of an attempt to convert a bi-articular muscle into a monarticular muscle in cerebral palsy patients with spasticity. (It was strongly recommended that reference be made to *Physiology of the Nervous System* by John F. Fulton, London, Oxford University Press, 1948.)

The operation described by the author consists in complete separation of the gastrocnemius from the Achilles tendon in the mid-calf region. The heads of the gastrocnemius are severed from the soleus, and the dissection is then extended upward in order to release all the small fibrous bands between the muscles and the deep fascial elements. The plantaris tendon is also divided.

The author reported that the results obtained by this operation in cerebral palsy patients with spasticity had been very satisfactory. The results were measured in terms of progress in walking. In the group of sixteen patients under ten years of age, twelve of the results had been considered excellent, one fair, and three poor. In the group of seven patients between the ages of ten and fourteen, all of whom had been walking before the operation, decrease of the tension in the gastrocnemius had produced good results in four, fair results in one, and poor results in two. Early operation before walking was emphasized.

In conclusion the author stated that recession of the gastrocnemius results in dimunition of the stretch reflex, which relieves heel-cord tension and adductor spasm. This makes possible a more erect walking position in the child who is just beginning to walk and also permits development of more normal labyrinthine reflexes. The author claimed that once abnormal patterns have been established, it is very difficult to change these patterns even after surgical correction of the equinus deformity.

Effect of Lengthening the Achilles Tendon on the Strength of the Gastrocnemius-Soleus Musculature. DR. LEWIS COZEN[30] and MRS. L. MARTIN[31] (Physical Therapist) reported their experiences with lengthening of the Achilles tendon in thirty patients. The strength of the gastrocnemius-soleus group was tested before and after the lengthening operations by means of a spring balance. These measurements were compared with measurements made in two children of the same age and sex. The normal values obtained by this measurement technique were rather low, the strength of a normal gastrocnemius in a fourteen-year-old boy being given as 9.3. (No normal values were determined for patients over sixteen years of age, although four of the patients in the series were over this age.) Considerable variation in results was found following the operation. Some muscles gained in strength, others remained the same, and some lost in strength. There were so many variables to relate to the problem that it was difficult to evaluate the factor of heel-cord lengthening alone as it affected the change in strength. The authors concluded that weakening of muscle strength after the operation can be expected if there is little motion at the ankle joint or if the equinus deformity cannot be corrected. Long periods of immobilization preceding or following tendon lengthening may also lead to weakening of the calf muscle group. It was the authors' impression that in most instances the triceps surae was not weakened following lengthening of the Achilles tendon.

In the discussion of the paper it was brought out that more careful controls and checking in the testing procedures were needed before it could be confirmed that improvements in strength had been obtained following lengthening of the triceps surae. Dr. Cozen thought that further study in this direction would be carried out.

Observation of Neuropathic (Charcot's) Joints Occurring in Diabetes Mellitus. DR. JULIAN E.

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JACOBS [32] reported his observations concerning neuropathic (Charcot's) joints in patients with diabetes mellitus and reviewed the literature on the subject, stating that he had found forty-eight cases recorded in the world literature. In ten years he had seen three cases at the Miller Clinic in Charlotte, North Carolina.

The first patient, a sixty-eight-year-old woman, who had been known to have diabetes for fourteen years, had a painful swelling at the base of the third metatarsal. Roentgenographic study revealed fragmentation of bone, and biopsy revealed bone spicules surrounded by cellular connective tissue in which there were closely packed small blood vessels and a prominent endothelial lining. The viable bone spicules were surrounded by osteoid seams and prominent osteoblasts. Seventeen months after the onset of the symptoms and eleven months after the biopsy, the bone had regenerated. Six years after the initial onset a destructive lesion of the fifth metatarsal head was found by means of roentgenograms; this lesion cleared spontaneously following limitation of weight-bearing. Ten years after the initial onset amputation of the second and third toes was required because of chronic ulcerations, although the roentgenograms still showed no bone abnormality.

Two other patients with diabetes, one a man of fifty-seven, the other a man of thirty, had typical neurotrophic joints. In the first man typical progressive disintegration of the bone elements of the fore part of the foot developed; in the second the same changes were found in the right ankle. The younger man was treated by below-the-knee amputation and used a prosthesis successfully for two and one-half years, until his death as a result of coronary thrombosis.

The treatment recommended by the author included adequate control of the diabetes, administration of vitamin-B complex or liver, avoidance of weight-bearing, treatment of ulcers, amputation when necessary, and use of appropriate apparatus such as shoes, supports, or walking casts.

Tuesday, January 29, 1957

Coxa Plana in Congenital Dislocation of the Hip. DR. GARRY DEN. HOUGH, III [33] presented a study of 160 dislocated hips treated at the New York Orthopaedic Hospital and the Springfield unit of the Shriners' Hospital. He found that in about 39 per cent of these hips coxa plana had developed. He also noted that in an additional 29 per cent there had been some disturbance in the epiphysis during the period of treatment which was not typical of coxa plana.

He pointed out that there was a higher incidence of coxa plana in patients with unilateral dislocation than in patients with bilateral dislocation. When coxa plana was present in patients with bilateral dislocation, the grade of change was the same on both sides. The incidence of coxa plana in patients with unilateral dislocation associated with contralateral dysplasia was the same as that in patients with unilateral dislocation alone. In nine of the ninety-seven patients with unilateral dislocation, coxa plana developed in the normal hip.

The incidence of coxa plana in males was not significantly higher than that in females; nor was it higher in patients with teratological conditions. The age at which reduction was done had a definite relation to the development of coxa plana. There was a decrease in incidence if the treatment was begun after the age of two. The author stated that if the initial reduction was obtained before the ossification center of the head had appeared, the incidence of coxa plana was 68 per cent. He noted that the severity of the coxa plana was directly proportionate to the length of delay of the development of the ossification center.

Legg-Calvé-Perthes Disease. DR. HARRY R. GOSSLING [34], DR. RUSSELL O. GEE [35], and DR. MAURICE M. PIKE [36] presented an evaluation of the treatment of 101 hip lesions in eighty-nine patients with Legg-Calvé-Perthes disease. These patients were seen over a twenty-year period, and the initial treatment in all cases consisted in recumbency in the Wu splint.

The patients were divided into five categories on the basis of the roentgenographic appearance of the hip at the time of admission to the hospital: (1) early sclerosis, as demonstrated by minimal clouding of the image of the capital epiphysis, with or without evidence of minimal absorptive changes in the metaphyseal area; (2) middle sclerosis, as demonstrated by the dense appearance of the epiphysis, by evidence of flattening, and by evidence of only minimal fragmentation and minimal absorptive changes in the epiphysis; (3) late sclerosis, as demonstrated by evidence of fragmentation; (4) early regeneration (hips in which regeneration had just begun); and (5) advanced progressing regeneration (hips which were in an advanced stage of regeneration).

The end-result evaluation was based on the functional status and roentgenographic appearance of the hip. The criteria used were as follows: (1) excellent: essentially normal anatomical appearance and normal function; (2) good: absence of symptoms, but presence of mild anatomical stigmata; (3) fair: extreme coxa

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magna, minimal loss of sphericity, and metaphysical shortening associated with mild limp and pain; and (4) poor or very poor: loss of sphericity, moderate to severe pain, and limp with restriction of hip motion.

The eighty-nine patients were followed for periods which ranged from six months to twenty-five years (six were followed over fifteen years; sixteen were followed from ten to fifteen years; twenty-one, from five to ten years; twenty-six, from two to five years; and twenty, less than two years). The average period of hospitalization was two years and nine months.

Of twenty-seven patients first seen when the disease was in the stage of early sclerosis, thirteen were treated by recumbency until healing was complete; the results in all these patients were rated *excellent*. The remaining fourteen patients in this group were permitted early weight-bearing. In seven of these patients the results were rated *good;* in five, *fair;* and in two, *very poor*. Of twenty-nine patients first seen when the disease was in the stage of middle sclerosis, eleven were treated by delayed weight-bearing; in eight of these patients the results were *excellent* and in three they were *good*. The remaining eighteen patients in this group were allowed early protected weight-bearing, the results being excellent in one, good in eleven, fair in three, and poor in three. Of twenty-eight patients first seen when the disease was in the late sclerotic stage, twenty-one were treated by recumbency until healing was complete; the results were excellent in eight and good in thirteen. The remaining seven patients were permitted early protected weight-bearing, the results being good in one, fair in three, poor in two, and very poor in one. Of eleven patients first seen when the disease was in the stage of early regeneration, eight were treated by recumbency until healing was complete; the results of this treatment were fair in three and poor in five. The other three patients in this group were allowed early protected weight-bearing. All had poor results. Of six patients seen when the disease was in the stage of advanced regeneration, all had a poor or very poor end result.

The authors pointed out that if the treatment by recumbency was instituted during the early, middle, or late sclerotic stage of the disease and was maintained until regeneration was complete, good or excellent results were obtained, but that if the principle of non-weight-bearing was not adhered to and there was either late institution of treatment or too early removal of protection the end results were deleteriously affected.

Dr. M. Beckett Howorth [37] pointed out that the results presented by the authors were similar to those described in other reported series. He called attention to the fact that the evaluation of end results in patients with Legg-Perthes disease is most difficult and requires careful objective study of the final anatomical result. To compare results in two different series similar methods of evaluation are essential. He felt that in the authors' series a longer period of follow-up would have been desirable, for forty patients were followed for less than five years, twenty patients were followed for less than two years, and some were followed for as short a time as six months. Some patients were not seen until so late that it was obvious that no form of treatment would be effective.

Dr. Howorth pointed out that there has been no basic change in the treatment of Legg-Perthes disease for the last twenty years and that the great need is to develop a better understanding of the pathology of the disease and to find a more definitive treatment.

Dr. Charles W. Goff [38] stated that he believes that in certain cases of Legg-Perthes disease the patient may be safely treated by early protected weight-bearing. These are the cases in which there is only spotty fragmentation in the non-weight-bearing zone of the femoral epiphysis.

Experience with the Use of the Milwaukee Brace for Paralytic Scoliosis. Dr. James B. Wray [39] and Dr. C. Edwin Irwin [40] presented a paper based on their observations of a group of 117 patients with paralytic scoliosis treated by means of the Milwaukee brace. The authors adhered to the general principles of the Milwaukee brace but made a few minor alterations in its construction and application. The authors used this brace for two main purposes. In children who were considered too young for surgical fusion, it was used as a conservative holding device, while in patients who were not considered good anesthetic risks because of their paralytic involvement, it was used as a substitute for surgery. In a third group the brace was used both preoperatively, to obtain correction of the curve, and postoperatively, to obtain immobilization. It should be definitely noted that all of the 117 patients on whom it was used had paralytic scoliosis as a result of poliomyelitis. The authors felt that in their series this brace was successful in halting the progression of the curve in 81 per cent of the patients for whom surgery was not the treatment of choice. They pointed out, however, that the brace should not be used to replace spine fusion in the management of severely progressing curves.

If any mistake was made in this series, it was that several of the patients were allowed to wear the brace too long and that correction and operative fusion could have been done earlier. The authors concluded that the Milwaukee brace has a definite place in the treatment of paralytic scoliosis, but that by itself it is not the whole answer to this problem.

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[38] 30 Farmington Avenue, Hartford 5, Connecticut.
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The Milwaukee Brace in the Treatment of Scoliosis. Dr. Walter P. Blount [41] and Dr. Albert C. Schmidt [42] described in detail the Milwaukee brace and its present construction, giving briefly the history of this brace from its earliest use over ten years ago to the present. The operative technique used by the authors in the treatment of scoliosis was described briefly and their errors in technique were stressed. Further details were given as regards the use of the Milwaukee brace (1) preoperatively to postpone surgery, (2) as a means to obtain immediate postoperative immobilization, and (3) as a means to maintain postoperative correction and immobilization.

Eighty-seven patients with scoliosis had been operated upon by the authors. In this series there were no deaths and no neurological complications. The results were analyzed as to improvement in degrees of correction. The total average net correction was only 16.6 degrees, which represents an improvement of only 27.2 per cent. The clinical and psychological gains were far greater than this critical measurement would indicate, however. The authors pointed out some of the reasons for the poorer results, including the use of homogenous bone. They stressed the importance of early recognition and treatment of pseudarthrosis. Pseudarthrosis should be anticipated and repaired promptly.

The conclusion of the authors was that the Milwaukee brace can be used, quite justifiably, to prevent a curve from increasing until the child is older, when surgical intervention becomes necessary. In selected cases it may be applied preoperatively only to accustom the patient to the skin pressure, and then reapplied on the operating table as a means to obtain immediate postoperative immobilization. Its function as a means to obtain postoperative correction was stressed since, in the current method of operative treatment, no attempt is made to obtain correction prior to surgery. All correction is obtained by the use of the Milwaukee brace after surgery.

Follow-Up on Scoliosis. Dr. Joseph C. Risser [43] and Dr. Donald M. Norquist [44] presented a follow-up study of patients treated for scoliosis by spine fusion. This series included the patients treated at the Los Angeles Orthopaedic Hospital during the period 1935 to 1950 as well as the patients from the authors' private practice treated during the period 1935 to 1956. Among the 347 patients upon whom 619 spine fusions were performed, there was one fatality and three instances of postoperative paralysis. The paralysis occurred in patients with severe kyphosis as well as scoliosis. Two of the patients with paralysis recovered partially following laminectomy. The age range in this series was from one and one-half to thirty-nine years. Correction of the deformity was obtained by means of either a hinged jacket or a localizer cast. Spine fusion was performed by the Hibbs technique, extra bone from the tibia being used in twenty cases and particular attention being paid to fusing the facets in the more recent cases. In the cases in which the hinged jacket was used, the patients were kept recumbent for three months after the operation and then were allowed to be ambulatory in a body jacket. The average total time in plaster was nine months. In the cases in which the localizer cast was used, the cast was changed seven to ten days after the operation, the patient then being allowed to be ambulatory. The cast was reapplied at three to four month intervals.

Follow-up studies were completed on 242 patients. In seventy-five of these patients the scoliosis was secondary to anterior poliomyelitis, while in 167 patients it was idiopathic or, as the authors prefer to call it, metabolic in origin. Of the 183 patients treated by means of a hinged jacket, ninety-two were followed for from five years to more than twenty years, while of the fifty-nine patients treated by the localizer cast, forty-two were followed for from two to four years. The remaining patients were followed for shorter periods. The final result was determined by comparing anteroposterior roentgenograms made (with the patient standing) at the time of follow-up with similar roentgenograms made before treatment. The results were classified as *excellent*, *good*, *fair*, and *poor* according to criteria based on the amount of correction maintained. Among 177 patients treated by means of the turnbuckle jacket, the results in 127 (72 per cent) were classified as *good* or *excellent*, while among the sixty-two patients treated by the localizer cast, the results in forty-eight (77 per cent) were rated as *good* or *excellent*. The poor results with loss of correction were found to be due to the following factors: (1) too short or too long a fusion area, usually the former, (2) an ineffective cast (more loss of correction occurred with the turnbuckle cast than with the localizer cast), and (3) a delay in fusion or the development of pseudarthrosis. The incidence of pseudarthrosis was 23 per cent in the group treated by the turnbuckle cast and 17 per cent in the group treated by the localizer cast. Pseudarthroses were more common in the patients with the more flexible thoracolumbar and lumbar curves than in the patients with thoracic curves; they were also more common in the patients with poliomyelitic deformities than in the patients with metabolic deformities. The loss of correction was influenced by growth. When spine growth was complete but there was inadequate fusion, loss of correction occurred while the patient was still wearing the cast or soon after the removal of the cast; there was no further loss after this time, however, and in none of these patients did the curve increase beyond the degree of severity shown in the original roentgenogram made with

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the patient standing. In the patients in whom vertebral growth was incomplete and the fusion inadequate as to length and strength, the deformity tended to increase to more than the original degree of severity unless the defect in the graft was corrected by a second operative procedure. The average loss of correction in patients having such a second operative procedure was 8 to 10 degrees.

Repair of the Articular Surface of the Femoral Head Following Arthroplasty. Dr. Marshall R. Urist [45] presented a study of repair of the articular surface of the femoral head following arthroplasty. This study was based on a series in which the head of the femur was excised, during revision or fusion, in nine patients upon whom the Smith-Petersen mold arthroplasty had been done and in six patients upon whom the Vitallium hip-socket arthroplasty had been done. The revisions were performed six to sixty months after the original arthroplasties, which had been performed for rheumatoid arthritis in seven cases, for degenerative joint disease in two cases, and for avascular necrosis in six cases. The specimens were sectioned by means of a band saw in order that gross and roentgenographic examinations could be made. Special histochemical preparations were then made in order to observe (1) fibrinoid, (2) ground substance, (3) reticulin, (4) collagen, (5) cartilage, and (6) new bone at various stages of repair.

Three stages of repair were observed. The first stage was completed within six months and consisted in the development of a loose layer of fibrinoid and fibrous connective tissue that originated from the reticular cells of the marrow. The second stage was completed at one year and consisted in progressive transformation of the fibrinoid into fibrocartilage. The third stage began at about eighteen months and continued for several years; it consisted in further development of fibrocartilage. It was noted that in areas of dead avascular bone, there was no fibrocartilaginous covering and the bone became eburnated. In contrast, all living bone was covered by fibrocartilage of varying thickness. The author stated that new cartilage is derived from the endosteum of viable bone.

In those specimens obtained several years after the original arthroplasty, it was found that the diameter of the osseous head of the femur was less than the diameter of the neck although the over-all diameter was greater. The explanation for this finding was that the new fibrocartilage increases in thickness at the expense of the bone tissue replacing it.

In patients in whom avascular necrosis develops in the head of the femur following arthroplasty, fibrocartilage does not form, resorption occurs, the joint disintegrates, and the mold eventually comes to rest on the trochanter, resulting in instability of the hip and pain.

Osteotomy — Bunionectomy for Severe Hallux Valgus. Dr. C. Leslie Mitchell [46] presented a further report on an operation for hallux valgus which he had originally described in 1945. At that time he had emphasized the role played by metatarsus primus varus. The operation he described consists in lateral-displacement, angulation osteotomy of the first metatarsal neck to correct the metatarsus primus varus and medial capsulorrhaphy to correct the valgus deformity of the hallux.

The author reported that in most of his patients with severe hallux valgus the intermetatarsal angle was from 10 to 22 degrees. He stated that when this angle was over 10 degrees, correction of the toe deformity alone, without simultaneous correction of the metatarsal deviation, will often lead to recurrent deformity. He had found distal osteotomy to be a simple and sure method of correcting the metatarsus primus varus. The slight shortening that occurs as a result of the osteotomy allows full relaxation of the lateral capsule and adductor hallucis so that no lateral release of the metatarsophalangeal joint is required. The hallux will remain in a normal position if adequate medial capsulorrhaphy is done; and if a combination of exostosectomy and lateral shift of the metatarsal head is performed, a significant narrowing of the foot may be obtained. It was emphasized that a good result obtained by this operation will be superior to a good result obtained by excision arthroplasty.

In the author's series 100 feet in fifty-nine patients had been operated upon. The average follow-up was eight years. In the final evaluation it was found that 80 per cent of the patients were totally satisfied and that the results in 82 per cent of the feet were rated *good* or *excellent* by the surgeon.

There was a high correlation between the result and the range of motion in the metatarsophalangeal joint. In 87 per cent of the patients in whom a significant decrease of the metatarsus primus varus was obtained (the residual deformity being less than 10 degrees), good or excellent results were obtained. No correlation was found between the presence of mild postoperative shortening of the first metatarsal and the development of secondary metatarsalgia. If the first metatarsal head was depressed at the osteotomy site, the preoperative metatarsalgia was likely to be relieved or improved.

In conclusion, the author stated that, when done correctly in a suitable patient, the operation has merit. The results can be improved by attention to technical details and by careful selection of patients.

Familial Osteochondritis Dissecans with Associated Tibia Vara. Dr. William J. Tobin [47] pre-

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sented a historical review of osteochondritis dissecans. He stated that the findings in some of his cases strongly suggest the possibility that some types of osteochondroses are familial traits which are produced as hereditary conditions. He observed that if osteotomy is performed too early in the correction of tibia vara, the result will be poor.

Fixation of Intracapsular Fractures of the Femur with Multiple Nails. End-Result Study. Dr. Michael T. Modny [48] and Dr. Harold G. Kunz [49] described the mechanical problems involved in internal fixation of intracapsular hip fractures and reviewed the basic principles of valgus reduction and rigid internal fixation. The advantages of the four-pin technique described by A. T. Moore were enumerated, and the technique of inserting the pins with the aid of a guide developed by one of the authors (M. T. M.) was presented in detail. The authors reported that this method had been used in twenty-five patients. All these patients were followed for at least a year and bone union was uniformly obtained. Intra-articular protrusion of the nails occurred in two patients, but in spite of this, bone union occurred. Because of the short period of observation, no conclusions were offered concerning the incidence of avascular necrosis.

Traumatic Periostitis in Children. Dr. Morris S. Friedman [50] stated that in infants and children periostitis lesions are most frequently the result of trauma. While in most cases the history of trauma is definite, there are cases in which the bone lesion cannot be readily related to trauma. In some of these cases, the history of trauma is purposely withheld because of guilt on the part of the parents, siblings, or others. Characteristically, the lesions in these cases are of the ossifying-periostitis type which frequently has an elaborate and bizarre appearance. Erroneous diagnoses have been common; these have included acute osteomyelitis, malignant neoplasm, scurvy, and the luetic type of periostitis. The findings of roentgenograms made immediately after the injuries are generally negative, for ossifying periostitis does not appear until after seven to ten days. The periosteal changes in traumatic ossifying periostitis follow a characteristic course which consists mainly in steady resolution of the lesion over a period of several weeks. In some cases, a fracture line or a slight degree of epiphyseal separation is found. It is important to recognize this lesion in order not to overdiagnose or overtreat and in order to prevent subjection of the child to an extensive regimen of laboratory examination and biopsy. The author reported seven cases. He also described a case of Caffey's disease and a case of scurvy in order to illustrate the differential diagnosis.

Detailed X-ray Study of the Lumbosacral Spine in Normal Children Aged Five to Fifteen. Dr. C. A. Splithoff [51] reported a study made in order to determine the width of the lumbosacral disc, the sacral angle, and the incidence of congenital abnormality of the lumbosacral spine in 100 children.

It was found that the posterior width of the lumbosacral disc varied from zero (in fifteen children) to five millimeters, the average width being three millimeters. The sacral angle varied from 5 degrees to 49 degrees, the average being 31.6 degrees. The most common abnormality found was spina bifida, and the second most common abnormality was the presence of transitional vertebrae at the fifth-lumbar or first-sacral level. Three patients had a spondyloschisis, but none had a spondylolisthesis. Although the number of patients was small, the findings of this study with regard to abnormalities closely paralleled those of similar studies. The author concluded that the lumbosacral spine with which a child is born "is altered only by profound disease or attritional factors".

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Report of the Fracture Committee on the Use of a Prosthesis for the Treatment of Fresh Femoral-Neck Fractures. Dr. Fred C. Reynolds [52] reported the experience of the Fracture Committee in the use of the femoral-head prosthesis in the treatment of fresh fractures of the neck of the femur.

Over a four-year period 270 patients had been treated by this method by members of the Fracture Committee. The average age of these patients was seventy-three, the average interval between injury and operation was twelve days, and the average length of postoperative hospitalization was thirty-five days. There was a total of seventy-seven postoperative complications, including four major infections. During the insertion of the prosthesis, seven dislocations and six fractures had occurred. The average period of follow-up was a little over twenty-two months.

In 58 per cent of the patients the result was considered satisfactory, but "there were no hips restored to the same functional capacity that was present prior to fracture". The metal intramedullary-stem type of prosthesis gave a slightly higher percentage of satisfactory results than any of the other types used.

When the results in this series of fractures treated by the insertion of a prosthesis were compared with the results obtained by internal fixation in a series of hip fractures reported in 1939, it was found that the per-

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[50] 315 Sherland Building, South Bend 1, Indiana.
[51] 3406 Webster Street, Oakland 9, California.
[52] 4960 Audubon, St. Louis 10, Missouri.

centage of satisfactory results in the two series were almost identical. The Committee concluded that "there does seem to be a place for the prosthesis in the management of fresh femoral-neck fractures" and recommended that the procedure be used (1) in the old, relatively poor-risk patient who will probably be able to tolerate only one surgical procedure, (2) when early ambulation is essential and the condition of the patient makes the use of a walker or crutches impractical, (3) in patients who have Parkinson's disease or spastic paralysis, and (4) when satisfactory reduction and fixation of the fracture cannot be obtained even by open operation.

Twenty-Five Year Follow-Up of Limb-Lengthening Procedures. Dr. Harold A. Sofield [53], Dr. Sidney J. Blair [54], and Dr. Edward A. Millar [55] presented an analysis based on long-term follow-up of the limb-lengthening operations done at the Shriners' Hospital for Crippled Children in Chicago. The average time between the surgery and the most recent follow-up examination was twenty-two years, the longest period of follow-up being twenty-eight years.

In all cases the follow-up data were obtained by means of complete physical examinations carried out by the authors. A brief description of the operative technique and the apparatus used was given.

Of the sixty-three limb-lengthening operations which were done, fifty-five involved the tibia and fibula and eight involved the femur. In the forty cases analyzed, twenty-six operations were done for poliomyelitis, five for osteomyelitis or pyogenic joint disease, one for tuberculosis of the hip, three for congenital shortening, three for epiphyseal injuries, and two for old unreduced congenital dislocation of the hip.

Almost all the patients in whom tibial lengthening was done had foot deformities of some type, the more common of which were equinus deformity, valgus deformity, and the presence of rigid multiple joints.

The authors stated that the complications which they had considered as most likely to occur and which might have been regarded as conclusive evidence against use of the procedure failed to materialize. In only three cases were there any serious infections, and these occurred in patients who had had previous bone or joint disease. There were no instances of non-union or delayed union. Transitory neurological changes were found in five patients, and permanent loss of sensation was found in two patients. The most severe complication occurred in a patient with congenital bowing of the tibia and resulted in below-the-knee amputation. The authors pointed out that this limb probably should have been amputated immediately, without any attempt to perform a lengthening procedure.

The authors stated that if only these types of complication were considered, one could probably justify use of the operation in the majority of cases. They pointed out, however, that the principal disadvantage of limb lengthening is that it is followed by marked reduction in muscle power. This was found not only in the patients with poliomyelitis but also in the patients who had had excellent musculature in the extremity prior to the lengthening procedure.

In their summary and conclusion, the authors stated that limb-lengthening operations are seldom justified and that limb-shortening or growth-arrest operations are much to be preferred. They pointed out that improved function, not just increased length, is the objective of treatment.

Shortening of the Metatarsal Shaft for Correction of Plantar Keratoses. Dr. Nicholas J. Giannestras [56] described a method of treatment for plantar keratoses which are caused by the presence of pressure beneath the head of one of the metatarsals. (The microscopic and macroscopic differences between a verruca plantaris—plantar wart—and a plantar keratosis were presented.) The principal feature of this method is surgical shortening of the metatarsal shaft, so that its head is retracted proximally, which relieves the pressure.

The technique of this surgery is not difficult. For four weeks after the operation the patient is required to wear a plaster cast. In the author's series a total of forty procedures were performed upon thirty-one patients. Of these forty procedures, thirty-three produced excellent results and four produced good results. At the time of writing two of the patients with poor results planned to undergo surgical shortening of a second metatarsal, but the third patient had so little discomfort that she did not wish additional surgery.

Functional Fixation of Intracapsular Fractures of the Femur. Dr. William K. Massie [57] presented a historical review of the mechanical problems encountered in the treatment of displaced femoral-neck fractures. Accurate reduction in the frontal plane with the head fragment placed in valgus and anatomical reduction in the sagittal plane is of prime importance. A simple manipulative method was described. Fixation is provided by an adjustable (four and one-half to six and one-half inches) telescoping flanged nail which is inserted at an angle of 155 degrees to the femoral shaft. The nail thus parallels the medial trabeculations

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[57] 288 South Limestone Street, Lexington 1, Kentucky.

and weight-bearing axis of the femoral neck, which is prevented from retracting by the use of a two-hole plate. No lateral bolt or nut is required. This method of fixation permits forcible impaction of the fragments at surgery which ensures absolute immediate immobilization of the fragments.

In the author's series the telescoping fixation device eliminated the complication of nail intrusion into the acetabulum but permitted constant impaction of the fragments when inadvertent unauthorized weight-bearing occurred. Union was obtained in 98 per cent of the forty-one displaced femoral-neck fractures treated by this technique, an incidence which compares favorably with the 24 per cent incidence of pseudarthrosis in a series of twenty-one similar fractures treated by the author previously by means of a rigid nail. The follow-up period of one to three years was inadequate for a reliable estimate of the incidence of avascular necrosis. It was concluded that non-union of displaced fractures of the femoral neck may be routinely prevented in spite of unauthorized weight-bearing if absolute immobilization of the fragments can be maintained. The author's method is one means of attaining this.

Iliopsoas Transplant—Femoral Osteotomy for Paralytic Dislocation. Dr. Joseph L. Fleming [58] gave a historical review of the treatment of paralytic dislocation of the hip, including surgical methods designed to strengthen the abductors and extensors. The pathomechanical role of muscle imbalance, flexion and adduction contracture, coxa valga, femoral anteversion, acetabular insufficiency, and other factors was discussed. It was felt that muscle imbalance was the primary cause of dislocation, but that coxa valga, anteversion, and acetabular insufficiency had important secondary roles. As a result of intermittent flexion, external rotation, and adduction, a hip with weakened abductors and extensors is gradually levered laterally, superiorly, and posteriorly. Successful treatment is dependent upon the correction of the muscle imbalance, femoral deformity, and acetabular insufficiency.

The operation used by the author consisted in transfer of the iliopsoas insertion to the greater trochanter as described by Mustard, rotation osteotomy, and, in one patient, varus osteotomy of the femur. This operation may be completed in one stage. Correction of the acetabular inadequacy or capsulorrhaphy, if indicated, should be accomplished before the transferred muscle is attached to the greater trochanter. The early results in three patients were gratifying. In two of the patients the dislocation was due to poliomyelitis, and in the other it was due to meningomyelocele.

In discussion, Dr. Floyd Jergesen [59] stated that although transferred muscles may be trained to participate in unaccustomed voluntary and purposeful movements, it is difficult to train them to perform functions which require a change in phase and to co-ordinate in automatic activities such as walking. He quoted the work of Inman and his associates as having shown that the iliacus and major hip abductors were nonphasic during walking. He claimed that it must be demonstrated that the transferred iliopsoas undergoes an alteration in phase before it can be claimed that its beneficial effect during walking is the result of active reinforcement of the abductors. Otherwise, the improvement in gait caused by the iliopsoas transfer might be attributed to other factors such as removal of the deforming muscle action, the presence of passive support, or the spontaneous recovery of muscle function following the corrective operation.

Treatment and Prevention of Paraplegic Pressure Sores. Dr. J. Treacy O'Hanlan [60] discussed the treatment of decubiti (pressure sores) in patients with transverse myelopathy. He stated that all decubiti can be prevented by good nursing care, which includes frequent change of position, skin massage, and passive exercise.

Ischial decubiti are caused by the concentration of great pressure upon small areas of the ischial tuberosities as a result of constant sitting. These decubiti can be prevented by having the patient perform push-ups in the wheel chair and by the use of a cut-out padded seat which transfers weight-bearing to broader surfaces such as the upper ends and shafts of the femora. The ischial decubitus, which starts as bursitis, progressively develops into overlying skin necrosis and ulceration, periostitis, and finally osteomyelitis of the underlying bone. Treatment consists in ischiectomy with excision of the ulcer. The dead space is obliterated. The drainage ceases on the twenty-first day when the sutures are removed, and the patient is allowed to sit up on the thirtieth day and may use his braces shortly thereafter.

Sacral decubiti are treated by the removal of the coccyx and lower portion of the sacrum, while trochanteric ulcers are treated by removal of the greater trochanter. Patellae, iliac spines, and malleoli may also be removed with impunity when ulcers occur in these areas.

The use of these procedures in patients who are not paraplegic is not recommended.

Congenital Absence of the Fibula. Dr. T. Campbell Thompson [61], Dr. Lee Ramsey Straub [62], and

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[62] 535 East 70th Street, New York 21, N. Y.

DR. WILLIAM D. ARNOLD [63] presented a study of thirty-one cases of congenital absence of the fibula in twenty-five patients. These patients were treated at the Hospital for Special Surgery from 1939 to 1955. The consistent pattern of the deformity, the frequent presence of a tight deforming band, and the effect of early excision of this band were emphasized.

The abnormalities which were observed included hypoplasia of the whole extremity, absence of the fibula, bowing of the tibia, equinovalgus deformity of the foot, and anomalies of the tarsal and metatarsal bones. A tight band of fibrous tissue was found in eighteen of the thirty-one extremities, an incidence of 58 per cent. This band was an important factor, for in almost every case the equinus component of the deformity could not be corrected until this band had been divided.

The surgical procedures that had been performed on these patients consisted in excision of the tight band, lengthening of the heel cord, posterior ankle capsulotomy, transfer of the peroneal tendons, osteotomy of the tibia, epiphysiodesis, and amputation.

In eight young children, only excision of the deforming band was carried out. In each of these children the equinus factor was corrected, the valgus factor lessened, and the bowing of the tibia reduced. The only factor not affected was the major discrepancy in length.

On the basis of their results the authors believed that treatment should include excision of the tight band as well as the release of any other soft-tissue contracture in the calf and that this treatment should be carried out at the earliest possible age. In their series, this treatment resulted in better position of the foot and a better gait and yet made it possible for a Syme's amputation to be done later if indicated.

Compression Technique in Ununited and Infected Fractures. MR. THOMAS KING [64] presented a study of forty-nine ununited fractures and four fresh fractures treated by compression. His purpose in this study was to determine the clinical value of compression and to investigate the method by which it could be best obtained. He presented a summary of previous studies on compression, describing Wolff's studies of 1870, the work of Key, Charnley, and von Volkmann, and the experiments of Eggers, Shindler, and Pomerat.

Mr. King implied that, in order to obtain the best results, apposition of cancellous bone should be secured when possible. In his own clinical cases his object was to apply the stimulus of compression on the bone ends, in accordance with the Wolff doctrine. This method of application was used in order to determine whether it was beneficial in promoting new bone profusely and quickly.

After considering the data on the fifty-three patients in the total series and after studying the evidence for and against compression, the author did not make any definite commitment as to whether he thought compression was or was not a definite factor in securing osseous union. His general conclusion was that " . . . all these various views can only be considered with reserve. There are too many other and variable factors about which we know so little. And there I am prepared to leave the matter and confine myself to clinical observations."

In the group of forty-nine ununited fractures, there were eleven fractures of the humerus, nine of the radius, eight of the ulna, three of the femur, and eighteen of the tibia. Two methods of securing compression were used: (1) Greifensteiner's method in which two Kirschner wires were stretched in a stirrup and tightened so as to bring the fractured fragments into apposition with compression, and (2) the Steinmann-pin method in which elastic bands were placed around the ends of Steinmann pins on both sides in order to produce compression. In both these methods, the amount of compression applied was twenty-five pounds.

The author concluded that for fractures of the humerus and femur, Greifensteiner's method was probably better, while for fractures of the tibia, the Steinmann-pin method was to be preferred. The use of either method in the forearm was discouraged.

Thirteen of the patients with ununited fractures also had draining sinuses. In 92 per cent of these patients there was osseous union, and the draining of the sinuses ceased. In 8 per cent there was non-union. In the total series of forty-nine patients, including those with draining sinuses, there was bone union in 83.7 per cent and non-union in 16.3 per cent. Attention was called to the fact that all of these fractures were difficult to treat and some of them were extremely comminuted. In some patients further operative procedures were done in an effort to increase the cancellous-bone contact and to retain the original length of the bone. These procedures included spiking one fracture fragment into the medullary cavity of the other and placing bone grafts about the fracture site, the grafts being obtained from the comminuted fragments in the area of the fracture. The four recent fractures with gross displacement united.

The author concluded that compression is of real value in infected and ununited fractures, especially in those of the lower third of the humerus and the upper half of the tibia. Although there were no special complications in the author's series as a result of using either pins or wires to obtain compression in recent fractures, he felt it was not advisable to use compression techniques in these fractures, especially if the fracture was near a joint. The author stated that the use of compression did not appear to shorten the period required for bone union.

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Skeletal Changes in a Series of Sickle-Cell Cases. Dr. Richard W. Leong [65] presented a study of sickle-cell conditions. This study was based upon his observations in sixty-one cases. Sickling of the red blood cells is a phenomenon peculiar to the Negro race, and there is an incidence of approximately 10 per cent in this race in North America. In the vast majority of those affected (over 99 per cent), the condition is of the type known as the sickle-cell trait, a type which is heterozygous and is generally asymptomatic. The existence of a symptomatic type, sickle-cell anaemia (a homozygous condition), has been recognized since the appearance of Herrick's report in 1910, but the existence of the heterozygous condition (sickle-cell-hemoglobin-C disease) has been recognized only since the appearance of the recent work of Pauling and associates on abnormal hemoglobins. The manifestations of sickle-cell-hemoglobin-C disease are variable, ranging from a normal blood count and no symptoms to severe anaemia and disabilities characteristic of true sickle-cell anaemia.

Sickle-cell conditions may imitate many diseases including the following orthopaedic conditions: osteomyelitis, conditions resulting in osteoblastic lesions of bone, avascular necrosis of bone (particularly of the femoral head), diseases of the spine, bone tumors (such as enchondromata), rheumatic conditions, and neurological conditions (such as poliomyelitis, cerebral-spastic paralysis, and tumors of the spinal cord). Skeletal changes in the young child are primarily the result of bone-marrow hyperplasia (compensatory to chronic anaemia), while in the older child and the adult, the skeleton is affected by a variable composite of marrow hyperplasia, bone necrosis, and sclerosis. Involvement is usually bilateral and the humerus, femur, and spine are the structures most often involved. No specific skeletal change seen on the roentgenogram is diagnostic of sickle-cell bone diseases, but such changes are extremely helpful in directing the physician's attention to the possibility of sickle-cell diseases and in putting him on his guard against diagnosing the patient's condition as one of the diseases simulated by sickle-cell diseases.

a. Herrick, J. B.: Peculiar Elongated and Sickle-Shaped Red Blood Corpuscles in a Case of Severe Anemia. Arch. Int. Med., **6**: 517–521, 1910.

b. Pauling, Linnus; Itano, H. A.; Singer, S. J.; and Wells, I. C.: Sickle Cell Anemia, a Molecular Disease. Science, **110**: 543–548, 1949.

Multiple Myeloma. Dr. Bradley L. Coley [66], Dr. Norman L. Higinbotham [67], and Dr. Kenneth C. Francis [68] presented a review of 163 cases of multiple myeloma seen between 1929 and 1955. A brief description of the disease was given, and the recent advances in diagnosis and treatment were emphasized. In twenty of thirty-five patients the gel-diffusion test revealed abnormal levels of serum globulin. The albumin-globulin ratio, the level of the total protein, and the findings of marrow aspiration are important factors in the diagnosis. The appearance or absence of lytic lesions in the roentgenograms is not considered diagnostically significant. The treatment of choice is administration of urethan, supplemented by appropriate roentgen therapy and orthopaedic measures, including intramedullary nailing of any fractures that occur. This form of treatment does not result in a cure, but it provides some palliation, and following it the patient may live somewhat longer than he would following other forms of treatment.

The Changing Bone Picture in Multiple Myeloma. Dr. William S. Smith [69] and Dr. Thomas J. Klug [70] described the findings of roentgenographic and clinical studies of fifty-eight patients with proved multiple myeloma. They found that 60 per cent of the patients either had no spine changes or had only osteoporosis without spine fracture. They suggested that "the diagnosis of multiple myeloma should be considered in any patient who had backache and osteoporosis". In the total group studied, almost as many patients without fractures of the vertebrae (thirteen) complained of backache as did those with fractures (fourteen). The authors made no comment on possible differences between the backache syndrome in patients with multiple myeloma and that associated with mechanical or arthritic spinal problems.

The Pathogenesis and Treatment of Idiopathic Scoliosis. Dr. Adam Gruca [71] presented a preliminary report of his experience in the use of stainless-steel springs and spring distractors in the treatment of idiopathic scoliosis. Dr. Gruca and his associates had become interested in the correction of the muscle imbalance found in scoliosis because of the discouraging results they had previously obtained by operative treatment.

In the first part of the paper, Dr. Gruca referred to findings of his associates which seemed to lend support to the theory that muscle imbalance is a predominant factor in idiopathic scoliosis. Dr. Thomas Zuk had observed differences in the chronaxy of the trunk muscles in patients with scoliosis, and histological ex-

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[69] University Hospital, Columbus 10, Ohio.
[70] Ohio State University Hospital, Columbus 10, Ohio.
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amination of muscles by Dr. T. Gorynski and Dr. M. Bojko had revealed changes in the muscles at the level of the primary spinal curve.

A mobile, anatomical model in which the muscles were represented by rubber bands and springs was constructed. It was found that segmental elimination of the muscles of the spine and the intercostals led to lateral curvature of the spine and rotation of the spinal column, the convexity always being on the side of the weakened muscles. On the basis of these studies the authors developed a method of treatment in which the weakened muscles on the convex side were replaced by artificial muscles. This technique, which they called alloplasty, involved the insertion of flattened spiral springs made of stainless steel. These springs were attached to the transverse processes of the terminal vertebrae of the primary curve. Other springs were also attached to the ribs and to the iliac crests. In patients with severe types of deformity, insertion of a spring distractor device on the concave side was done in combination with other surgical procedures.

The author reported the results obtained in three groups of patients. There were sixteen patients with first-degree scoliosis, that is, with a rigid angulation in the primary curve of below 30 degrees. In these patients, a correction of from 9 per cent to 100 per cent was obtained; the average correction, as measured when the patient was in the recumbent position, was 48 per cent, while the average correction, as measured when the patient was in the standing position, was only 28 per cent. These patients were followed for only two years.

In patients with second-degree scoliosis in whom the curve was rigid and the angulation was 30 to 60 degrees, alloplasty alone was not sufficient. In these patients the angulation was reduced to below 30 degrees either by use of a turnbuckle jacket or by surgical division of the contracted soft tissues. A screw spring distractor device was then placed between the transverse processes of the terminal vertebrae on the concave side of the curve. After the severity of the curve had been reduced to below 30 degrees, spring alloplasty was performed. The average correction obtained by the screw device, as measured with the patient in the recumbent position, was 40 degrees. Following the two-stage procedure, the average correction, as measured with the patient in the recumbent position, was 32 degrees.

Patients with third-degree scoliosis in whom there was a rigid angulation of greater than 60 degrees were treated by two-stage or three-stage procedures. In the first operation, the tight structures were released on the concave side of the curve, and a spring screw distractor was inserted. Some weeks later, a second operation on the convex side of the curve was performed: this operation consisted in excision of the articular processes and wedge resection of the intervertebral discs or vertebral bodies. During this same procedure, the springs were applied on the convex side of the curve. In adults, in a third procedure, the spine was fused.

The author concluded with the statement that this approach to the problem of scoliosis involves many unanswered questions. For example, the future of the springs within the soft tissues is yet to be determined, and no precise method to calculate either the degree of muscle imbalance or the exact power of the spring has been found. As a result of a two-year follow-up of about forty patients, it was the author's impression that it is possible to treat scoliosis in its early stages by simple and reversible means. Further follow-up is indicated before more definite conclusions can be drawn.

Thursday, January 31, 1957

Débridement and Panarthrodesis for Spinal Tuberculosis and Simulative Disease. Preliminary Report. Dr. R. H. Hall [72] and Dr. B. M. Adamson [73] described a method of surgical treatment of spinal tuberculosis which is designed to eliminate the focus of infection by direct attack. Included in their article was an excellent review of the literature.

The plan of treatment outlined by the authors included: (1) excision of the cavity walls, sequestra, and other débris; (2) an attempt to obtain solid bone fusion between both the vertebral bodies and the posterior elements; (3) prolonged immobilization; and (4) chemotherapy for at least one year postoperatively.

The lesion—including any débris or sequestra, the degenerated disc and scar tissue, and the sclerotic bone walls of the abscess—is debrided until the cancellous bone of the adjacent vertebra is exposed, following which milled granules of cancellous bank bone are packed into the cavity. About two months after the primary interbody débridement and grafting, a Hibbs-type posterior laminae and facet fusion of the diseased vertebrae is done. Only when the arthrodesis is considered solid is the patient permitted to become ambulatory. Twelve patients with suspected tuberculosis of the spine were treated by this method. In only seven of the twelve cases was a diagnosis of tuberculosis positively confirmed. In two cases the lesion was considered to be definitely non-tuberculous on the basis of bacteriological and microscopic examinations of the tissues, and in the remaining three cases the diagnosis was neither confirmed nor disproved. All of the nine patients who were followed for more than one year were considered to be cured; they had returned to their regular activities. The three patients who had been treated less than one year previously were progressing satisfactorily at the time of writing, but since treatment had not been completed, the disease could not be considered definitely arrested.

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[73] Veterans Administration Hospital, Long Beach, California.

Complications included two instances of abdominal-wall weakness and bulging as a result of the interruption of motor nerves during the operative exposure. In one patient draining through the posterior end of the incision started four months after the operation and continued for five months, when the sinus healed spontaneously.

Treatment of Tuberculous Bone Disease by Surgical Drainage Combined with Antibiotics. Dr. Mayer S. DeRoy [74], Dr. Harry Fisher [75], and Dr. Roy S. Temeles [76] described a method of treatment in which the principal feature is adequate opening of the area of infection so that complete drainage of the tuberculous lesion can be obtained. The authors reported a series of 194 operations performed on 172 tuberculous lesions in 142 patients. This included an end-result study of a previous series (reported in 1951) of fifty-two patients with sixty-three lesions treated by operation. In the operation used by the authors, all necrotic or caseous material and loose fragments of bone were removed from the area of destruction, but no curettage of the surrounding soft bone or tissue was carried out. The area was packed snugly with plain gauze, and the wound was left open. After twelve to fourteen days the gauze was removed, and thereafter only surface dressings were used. Various antibiotic drugs and combinations of these drugs were used during the course of the treatment. Patients were treated without immobilization of the joints and were made ambulatory as soon as possible following surgery. Arthrodesis of the joints was not done as a primary procedure and was rarely required as a secondary procedure. The authors stated that their results were good, and they concluded by saying that in their opinion these principles, which have been shown to be successful in the treatment of pyogenic disease, are even more successful in the treatment of tuberculous bone disease.

Fusion of the Spine for Tuberculosis in Children. A Long-Range Follow-Up Study. Dr. Mather Cleveland [77], Dr. David M. Bosworth [78], Dr. J. William Fielding [79], and Dr. Panayiotis Smyrnis [80] reported a clinical, scientific, and historical study which had been begun in 1929 and terminated in 1956, a span of twenty-seven years. This study included forty-two cases of spinal tuberculosis in children observed on the Orthopaedic Services of Seaview and St. Luke's Hospitals. At the time of writing eighteen of the patients were available for personal evaluation. Sixteen of these eighteen patients had been in poor general condition at the time of the operation. The average age of the patients at the time of surgery was five and one-half years, the youngest being 1.9 years old and the oldest being twelve. Two of the eighteen patients died of meningitis. The average length of follow-up was 21.7 years.

The tuberculosis involved various levels of the spine, the average number of vertebrae involved being five. Two patients were paraplegics prior to surgery but completely recovered following surgery. In three patients paraplegia developed following surgery; one of these patients died, but the other two completely recovered. Twelve of the eighteen patients had demonstrable abscesses, but only six showed residual calcification. In the total group of eighteen patients, thirty-six spine-fusion operations were performed as primary procedures and nine were performed as secondary procedures for pseudarthrosis. There were no postoperative deaths and no major complications.

The operative procedure used was basically the Hibbs-type fusion. These fusions were seldom successful without the addition of autogenous bone, from the ilium preferably. The average number of spine segments fused was nine, the shortest fusion including four segments and the longest, seventeen segments.

Of the sixteen patients who survived, nine were essentially normal as regards their activity status when last seen. In four patients the results were excellent although there was a mild kyphosis. In two there was considerable kyphosis, and in one marked kyphosis. Six (four females and two males) of the group were married and had children, all of whom were alive and well. It would seem that loss of lordosis occurred in the lumbar spine and was not compensated for by the development of real kyphosis. If several vertebrae were involved in the thoracic area, a rounded kyphos always developed; and if pseudarthrosis occurred, a sharply angulated kyphos developed. Growth of the fused area was noted, the average growth being one and one-half inches and the least growth being three-quarters of an inch. The anteroposterior and lateral diameters of the mass were observed to increase in thickness. The average loss of length in the fused area of the spine, as compared with the normal portions of the spine, was 49 per cent, while the average loss in height of the non-involved vertebral segments included in the fusion was 16.1 per cent. The lateral diameter of the undiseased vertebrae included in the fusion decreased by an average of 15 per cent, while the anteroposterior diameter of the undiseased bodies decreased by an average of 20 per cent.

Such factors as the loss in height of the diseased vertebrae, the changes in the transverse processes, the

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shape of the neural canal, and the loss in height of the vertebral-disc structures were described. The authors concluded that if tuberculosis of the spine in children is adequately treated by spine fusion, the patient, by the time he is fully grown, will have an excellent physical status.

Fracture of the Intercondyloid Eminence of the Tibia. Dr. Marvin H. Meyers [81] and Dr. Francis M. McKeever [82] reported a series of forty-five patients (ten adults and thirty-five children) with fractures of the intercondyloid eminence of the tibia. This fracture occurs less often in adults than in children, but when it does occur in adults, it is far more serious, for it usually results from great violence and, as a consequence, although the major damage is confined to the intercondyloid area of the tibia, there is also extensive damage to the supporting ligaments and the gliding surfaces of the knee joint. The results in adults are correspondingly poorer than those in children. Of the ten adult patients in the authors' series, eight had poor results and two had satisfactory results.

Of the thirty-five children, twenty-nine were between the ages of eight and thirteen. A fall from a bicycle was the most common cause of the injury. A rapidly developing effusion from the knee joint followed the trauma, and the joint was generally held in a position of flexion. Anteroposterior and lateral stability was usually undisturbed.

The fracture may not be apparent in the anteroposterior roentgenogram but is always detectable in a good lateral roentgenogram. The anatomy of the intercondyloid eminence and its relationship to the anterior cruciate ligament were discussed, and the author pointed out that the probable cause of the avulsion, that is, a violent forcing of the leg into a position of internal rotation, is a principal factor in the injury.

The fractures were classified into three types. In Types I and II there is minor displacement of the fragment, while in Type III the fragment is completely displaced and frequently rotated. Types I and II should be treated conservatively, but Type III requires open reduction. In this type, if replacement cannot be obtained by merely restoring the fragment to its original position, a simple absorbable suture passed through the thin edge of the avulsed fragment and then through the meniscus near its sharp margin will give adequate fixation. In patients with Types I and II the over-all results were very satisfactory; in fact, in twenty-five of twenty-seven patients, the results were considered excellent, while in one of the remaining patients, the result was considered only good because of slight instability. Of the eight patients with Type-III fractures, five had excellent results. One other had a good result with slight anteroposterior instability, and another had a loose body which required excision. The result in the third patient was not known.

Küntscher Method of Intramedullary Fixation. Dr. Gerhard B. G. Küntscher [83], noting that callus is extremely sensitive to mechanical stresses, emphasized that the basic principle in medullary fixation is that the internal splint, by means of flexible impingement of the nail in the medullary canal, produces a sufficiently stable osteosynthesis to immobilize the fracture completely throughout the healing process. Observance of this principle would seem to be the main requirement for the success of Küntscher's method, which his predecessors, obtaining less stable fixation, discontinued as unreliable. In contrast to those who adopt a dynamic approach to intramedullary nailing, Küntscher deliberately used the word *nail* rather than *pin*, stating that this appliance becomes firmly impinged in the bone by elastic forces in much the same manner that a carpenter's nail is retained and firmly seated in wood. Since the nail cannot uniformly fill the cross section of a medullary canal and since the bone will split if stretched only a few hundredths of a millimeter, so-called elastic impingement is achieved by using a nail which has a v-profile or clover-leaf design. As a result of compression of this nail against the sides of the bone, the fracture will be fixed with sufficient stability to withstand lateral, rotatory, and angular deforming influences.

Küntscher stated that use of a solid rod could not possibly result in stability. Noting that bone resorption takes place about any medullary appliance, he stated that the solid rod would soon become loose. By contrast, an elastic nail, with a compressible cross section, expands during bone resorption and thereby maintains mechanical fixation for a longer period of time. The necessity of having a nail sufficiently strong to withstand mechanical forces and the desirability of using the entire length of the medullary canal in order to obtain mechanical retention were stressed. Many times, the canal must be enlarged in order to hold a nail which is of proper size and strength. Properly done, this technique should rather uniformly produce an osteosynthesis which is sufficiently stable to make external splinting, such as application of a cast, not only meaningless, but harmful.

In his animal experiments and in his clinical cases, Küntscher noted that the extensive reaming used in his method produced no ill effects, either locally with regard to healing or systemically with regard to such factors as the development of fat emboli. Endosteal callus does not develop following the reaming, the endosteum being completely destroyed along with all endosteal blood supply, but this is compensated for by an increased development of intramedial and periosteal callus.

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Küntscher advocated the closed method of nailing but stated that to avoid the danger of fat embolism, the nailing should not be done until the fifth or sixth day. With regard to the development of fat embolism, he stated that it is "only caused by excessive pressure in the medullary cavity which, therefore, must be carefully avoided during nailing".

In the cases used as illustrations, the method achieved good results in the treatment of pseudarthroses. If the canal is reamed out sufficiently to insert a nail of adequate width and strength, further measures, such as removal of connective tissue, resection of bone ends, and bone-grafting, are unnecessary.

Fractures and Fracture-Dislocations of the Head of the Humerus. Dr. Robert A. Knight [84] and Dr. Ian A. Mayne [85] presented a study of forty adults who had sustained severe fracture or fracture dislocation of the articular surface of the humeral head. They divided their cases into four groups in order to better evaluate the methods of treatment and the end results. Fourteen of the fractures were treated by immobilization with or without previous manipulation. Eighteen were treated by open reduction, one was treated by resection of the humeral head, and seven were treated by the Jones reconstruction operation. In the group treated by the Jones procedure, there were three good results.

Marked limitation of shoulder function and aseptic necrosis of the humeral head were common findings both in patients treated by the closed method and in patients treated by the open method. Pain was not a common finding. Although motion was usually limited, often to a marked degree, the patients were generally more satisfied with the end result than were the surgeons.

The Patho-Mechanics of Peroneal Spastic Flat-Foot. Dr. Tom Outland [86] and Dr. Ian D. Murphy [87] presented a review of modern concepts concerning spastic flat-foot associated with tarsal anomalies. It was stated that these defects may be present in an apparently normal foot.

In the typical case of rigid-foot, characteristic changes in the head and neck of the talus occur accompanied by pain and spasm; these changes are more definite in patients with talosustentacular bar and posterior talocalcaneal bar. In the past the deformity of the head and neck of the talus was erroneously considered an arthritic change. The authors stated that the breaking and other changes in the head and neck of the talus are the result of a molding or remodelling process occurring in young children in whom the cartilaginous precursor of the talus is plastic.

Motion of the subtalar joint is obstructed by the presence of anomalies, with the result that the gliding motion of the navicular over the end of the talus is blocked and such limited motion as does occur at the midtarsal joint becomes a hinge motion. In this motion the upper edge of the navicular crushes into the plastic talar head and molds it into the characteristic shape which is recognized roentgenographically following completion of ossification. With abnormalities such as calcaneonavicular bar, which do not seriously reduce subtalar motion, the changes in the talar head are correspondingly absent or mild. In the defective talonavicular joint there may gradually develop degenerative arthritic changes which cause pain with associated peroneal spasm.

The precise mechanism by which peroneal spasm is produced has not thus far been demonstrated. The consistent presence of a deformity of the head of the talus in the patient with a typical lesion indicates that associated changes due to wear and tear irritate the terminal branches of the superficial and deep peroneal nerves, giving rise to reflex peroneal muscle spasm.

Operative Treatment of Recurrent Dislocation of the Patella in the Adult. Dr. Francis E. West [88] and Dr. Ralph Soto-Hall [89] claimed that most of the operations previously used to treat recurrent dislocation of the patella in adults have rectified the dislocation but have failed to treat the intra-articular complications which occur as a result of the original deformities.

In recurrent dislocation of the patella in the adult, there generally are severe degenerative changes in the articular cartilage of the patella and not infrequently there are also changes in the lateral condyle of the femur. These changes are the result of chondromalacia of the patella. The authors recommended patellectomy but stated that use of patellectomy without quadricepsplasty is illogical since it does not alter the abnormal mechanics which are present and which may cause recurrent dislocation of the tendon.

In their series, twenty-four operations were performed upon twenty patients. All the patients were adults with the exception of one, a child of twelve years of age, who had previously undergone unsuccessful operations. The adult patients had had no prior treatment other than support and exercise, except for one who had had patellectomy.

A detailed description of the operation was given. The distinguishing feature in this operation is the per-

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formance of quadricepsplasty. Following excision of the patella, the quadriceps tendon is separated and shifted medially and distally. The sectioned portion of the vastus medialis is then drawn laterally and distally and sutured to the quadriceps tendon. Quadriceps exercises are started early, and active motion is begun after three weeks.

In the twenty-two operations in which patellectomy combined with quadricepsplasty was done, the following results were obtained: fifteen excellent, six good, and one fair.

Dr. Emil D. W. Hauser [90] congratulated the authors on a well planned and well executed operation. He recommended that patellectomy with quadricepsplasty be done in the older patient who has chondromalacia or advanced arthritis of the knee. For the younger patient, however, he recommended total tendon transplantation, which he felt offers these advantages: an excellent cosmetic result is obtained, the patella protects the knee, and action of the patella gives better leverage and, thus, more power to the quadriceps. His experience with total tendon transplantation had been entirely satisfactory; in his series there had been no recurrences of the dislocation.

Dr. Ernest M. Burgess [91] agreed with the principle of combining patellectomy and quadricepsplasty and stated that he had used this operation satisfactorily in several cases. He congratulated the authors on their contribution.

Dr. Soto-Hall, in closing the discussion, emphasized the importance of intra-articular changes in the joint in patients with recurrent dislocation of the patella.

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SCIENTIFIC EXHIBITS

The Certification Movement and the Orthopaedic Surgeon. Mr. Lester A. Smith,[1] Assistant Director, the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc.

Certification of individuals and of brace and limb establishments has been a powerful force for higher standards in the decade, 1948 to 1957. Much of the leadership and creative force behind this movement has been contributed by orthopaedic surgeons, members of The Academy of Orthopaedic Surgeons.

The exhibit illustrated some of the factors in the achievements of this decade. Photographs of the ten Academy members who have served on the Board since its founding were shown: Dr. Rufus H. Alldredge, 1948–1950; Dr. Atha Thomas, 1948–1952; Dr. Henry H. Kessler, 1950–1953; Dr. Charles O. Bechtol, 1950–1953; Dr. Clinton L. Compere, 1951–1954; Dr. T. Campbell Thompson, 1952–1955; Dr. Robert Mazet, Jr., 1953–1956; Dr. Edward C. Holscher, 1954–1957; Dr. Roy M. Hoover, 1955–1958; and Dr. A. W. Spittler, 1956–1959.

One of these, Dr. Robert Mazet, Jr., served as President for the year 1955–1956. Currently, Dr. Edward C. Holscher of St. Louis is Vice-President.

Certification of both individuals and facilities implies careful checking of training, knowledge, ethics, and standing. The exhibit displayed on the punchboard samples of the various forms on which are recorded the judgment of the surgeon as to these points.

Publications displayed included:

1. *The Annual Registry* which is sent annually to over 10,000 physicians, agencies, and rehabilitation officials.

2. *The Orthopaedic and Prosthetic Appliance Journal* (and reprints) which is published as an educational aid for the prosthetist, orthotist, and other workers in this field.

The work of the orthopaedic surgeon and his research have given added emphasis to the skill of the certified orthotist and prosthetist. New appliances such as the Milwaukee brace demand the utmost in experience and training. Fundamental studies in such fields as muscle mechanics, phantom pain, and cineplasty will eventually affect the work of the prosthetist and orthotist. Drawings of the biceps-muscle tunnel and the effects of experimental injection of saline on phantom pain were displayed as examples of widespread research by surgeons.

The headquarters of the Certification Board are located at 411 Associations Building, Washington 6, D. C. Here are maintained the files on some 1,100 certified prosthetists and orthotists and some 350 certified limb and brace facilities in the United States and the Dominion of Canada.

[1] 411 Associations Building, Washington 6, D. C.

The Correction of Equinus in Cerebral Palsy. Dr. Henry H. Banks [2] and Dr. William T. Green [3] presented an end-result study of 129 patients with spastic cerebral palsy treated by surgery for persistent equinus deformity. The age range was from three to fourteen years; forty-one patients were under the age of five. There were eighty-eight males and forty-one females. There were five instances of monoplegia, fifty-four of hemiplegia, nineteen of paraplegia, and fifty-one of quadriplegia. All patients were seen more than two years after surgery; seventy-two patients were seen more than five years after surgery, and thirty-five patients were seen more than ten years after surgery. The factors involved in deciding on surgery were age, extent and character of motor involvement, balance, intelligence, deformity, previous conservative treatment, home situation, and follow-up care. In all, 236 operations for the correction of equinus deformity were performed in 129 patients. There were 164 heel-cord lengthenings, twenty-two fractional lengthenings of the gastrocnemius, twenty Stoeffel neurectomies, and thirty triple arthrodeses. Good to excellent results from lengthening of the heel cord, primarily by the sliding technique, were recorded in 70 per cent of the patients. These results were related to the proper choice of patient, the surgical procedure, and adequate postoperative care. Detailed care in the immediate postoperative period and long-term supervision are necessary after soft-tissue surgery. Protection with casts at night and exercises, particularly those to keep flexibility, may be needed throughout the growing period. Poor results were uniformly related to poor follow-up, poor cooperation, poor choice of patient, and failure to maintain correction. Eight instances of calcaneus, in six patients, were due either to overcorrection or to failure of protection postoperatively.

Fractional lengthening of the origin of the gastrocnemius was performed in mild cases of equinus deformity associated with flexion deformity of the knee. It was usually combined with hamstring lengthening and neurectomy of one head of the gastrocnemius. This technique is satisfactory when performed in patients with a mild degree of equinus deformity but otherwise is unsatisfactory.

A Stoeffel neurectomy of the gastrocnemius was primarily associated with a fractional lengthening of the gastrocnemius origin. In only three instances was the neurectomy performed alone. Only one of these presented a satisfactory result; this patient had only a mild degree of equinus deformity preoperatively.

Triple arthrodesis is not ordinarily indicated as a primary treatment of equinus deformity but may be recommended in those older patients with lateral instability and equinus deformity. Severe equinus deformity ordinarily requires other associated procedures, such as heel-cord lengthening with or without capsulotomy. If too much bone is removed in the triple arthrodesis, low rocker-foot will result.

Twenty-two secondary procedures were required in these 129 patients. Five relengthenings of the heel cord were performed; two of these, in retrospect, were unnecessary. Seven heel-cord lengthenings were necessary after neurectomy and fractional lengthening of the gastrocnemius had previously been performed in patients with more than a mild degree of equinus deformity. Two heel-cord lengthenings were required after bilateral Stoeffel neurectomy of the gastrocnemius was unsuccessful. Eight triple arthrodeses followed previous heel-cord lengthenings. These were required because of deformity other than equinus.

The procedure of choice for the correction of equinus deformity in cerebral palsy is usually a sliding lengthening of the heel cord. Other procedures may be indicated, either primarily or secondarily, by special circumstances.

Congenital Peritalar Dislocation. Vertical Talus, Osmond-Clarke. Dr. George Berkett [4] described the anatomical pathology of this condition and the results of preliminary management. The congenital peritalar dislocation described was limited to the deformity occurring in otherwise normal children and was not a complication of other conditions or treatment. One case in a newborn infant was presented in which complete correction was obtained within a short time by means of placing the calcaneus in full equinus and inversion.

In children treated after walking had begun, good correction was obtained by wedging the calcaneus in full equinus position which also brought the fore part of the foot into full equinus position. However, this resulted in full equinus deformity of the foot, although the relationship of the tarsus was relatively normal. The problems encountered in attempting to bring the foot out of equinus deformity were analyzed; these were primarily relaxation of the mid-tarsal joints, instability of the talocalcaneal relationship, and tight posterior structures. Methods of approaching these problems were discussed, but, because this was only a preliminary report, no specific procedures were advocated. It was brought out that treatment should be begun as early as possible in view of the fact that the dorsomedial portion of the foot is lengthened when the dislocation of the talus is reduced. It was made apparent that early correction is desirable before the soft tissues prevent adequate reduction because of the insufficient elasticity of these parts to accommodate the replaced talus.

The Treatment of Scoliosis with the Milwaukee Brace. Dr. Walter P. Blount [5], Dr. Albert C.

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SCHMIDT [6], MR. RICHARD C. BIDWELL [7], DR. E. DUDLEY KEEVER [8], and DR. EUGENE LEONARD [9] demonstrated by means of models the five stages in the manufacture of the brace:

1. The plaster negative was made over a partially corrected patient's torso with a constricted waistline.

2. A plaster positive was poured from the negative. This was skived in order to flatten the abdomen and to accentuate the prominence of the iliac crests. Additional felt padding was added to the anterior superior iliac spines. On the concave side, the thorax was built up with felt so that, when finished, the brace would be symmetrical.

3. The leather pelvic girdle was molded directly over the dry plaster positive, and the metal re-inforcements were added.

4. The brace was completed in the rough.

5. The finished brace was shown on the plaster model.

Four different live models were exhibited on consecutive days illustrating use of the brace in poliomyelitis to correct early deformity, the preoperative use of the brace to postpone surgery, the application of the brace as conservative treatment near the end of the growth period in idiopathic scoliosis and in scoliosis with juvenile round-back.

Transparencies of photographs and roentgenograms illustrated the use of the brace in connection with operative fusion of the spine in paralytic, idiopathic, and congenital curvatures at various intervals. These emphasized the need for prompt fusion in scoliosis when it can no longer be kept from progressing by the use of the Milwaukee brace with ambulation.

A Surgical Repair for Anterior Sternoclavicular Dislocations. DR. JOSEPH EDMUND BROWN [10] demonstrated that dislocation of the medial end of the clavicle is, percentagewise, rare. It may or may not be associated with avulsion-type fractures of the clavicle. They are of two types: (a) anterior which may become recurrent and (b) posterior or retrosternal.

The pertinent pathological findings preventing effective reduction are: ruptured costoclavicular ligament, displaced meniscus which blocks the joint space, and deforming force of clavicular head of the sternocleidomastoid. Reduction may be obtained, but dressings cannot satisfactorily maintain the reduction. The variously described positions and dressings, especially in the foreign literature, confirm this. A chronic dislocation or a recurrent subluxation may not produce a functional disability, but there is always a cosmetic one. Resection will alleviate the latter.

A method of operative repair of acute anterior dislocations was proposed. In this procedure the meniscus is removed, the deforming element (the clavicular head of the sternocleidomastoid muscle) is removed, and the clavicular head of the sternocleidomastoid is used in reconstruction of the costoclavicular ligament. The transfixation pin is used as a temporary measure to allow mobilization of all shoulder-girdle joints; it should be removed within three months.

Dr. Brown considers this procedure technically superior to fascial repairs, as proposed by Allen and Bankart, and to wire-suture repairs. Ten patients have been treated by this method. In all the dislocation remained stably reduced. Complications were encountered in three patients: the transfixation pin broke at the joint level in two cases; this necessitated "windowing" of the sternum in order to recover the distal half of the pin. One pin was misdirected and protruded into the mediastinum and penetrated the pulmonary artery, producing a pericardial tamponade which necessitated a thoracotomy.

Changes in the Femoral Head Following Intracapsular Fracture. DR. SHERMAN S. COLEMAN [11], DR. CLINTON L. COMPERE [12], and DR. M. O. TACHDJIAN [13] presented observations on sixty excised femoral heads. The specimens were derived from hips with a variety of conditions which resulted from fracture and which developed twenty-four hours to eleven years after fracture. All specimens were studied histologically, and the preoperative roentgenograms of the specimen and the microscopic features were correlated. Observations were illustrated by sample case histories in which transparencies of roentgenograms and photomicrographs were used.

The specimens were grouped and studied chronologically. Twenty-five femoral heads were removed during the first three weeks following fracture. In nearly all of these some necrosis of bone was encountered, particularly in the subchondral zone, at the fracture line, and scattered at random throughout the head. None of the femoral heads removed during this three-week period showed complete necrosis, and in most of those removed at four to five days following fracture, active osteogenesis was noted.

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[7] 535 North 27th Street, Milwaukee 8, Wisconsin.
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[10] St. Luke's Hospital, Cleveland, Ohio.
[11] 720 North Michigan Avenue, Chicago 11, Illinois.
[12] 720 North Michigan Avenue, Chicago 11, Illinois.
[13] 720 North Michigan Avenue, Chicago 11, Illinois.

Four specimens were removed between three and eight weeks after fracture, following failure of earlier treatment. As compared with the earlier group, these heads showed either increased amounts of necrosis of bone or increased evidence of viability in the form of osteogenesis and active reorganization.

Between the two-month and six-month period, eight specimens were studied, all derived from cases of non-union. The histological findings do not change greatly during that four-month span. At two months, many of the histological features of non-union are present at the fracture site, and, at this time, the femoral heads are either mostly alive or mostly necrotic. The early definite changes in the roentgenograms are detected in this period, but there is no consistent correlation of these changes with the microscopic findings.

At six months and beyond, additional pathological changes in the femoral head take place. These vary depending upon whether union or non-union has occurred. In cases of non-union, the femoral head generally retains its original shape and contour, but histologically it exhibits either disuse atrophy with predominantly viable bone or the advanced changes of necrosis. With union, and following protracted weight-bearing, the femoral head may begin a slow insidious process of breakdown. Gradual collapse of various portions of the articular cortex and subchondral bone are the early signs seen roentgenographically; later, areas of increased and decreased density appear. It is difficult to correlate these changes in density with the histological findings, for increased density in such circumstances may represent zones of hypertrophied living bone (sclerosis) or it may represent necrotic bone with reactive bone about it. With weight-bearing femoral heads, "relative" density changes are invalid and do not conform to a single microscopic pattern. The degenerative sequelae of avascular necrosis, although similar, differ in many respects from the degenerative changes occurring in malum coxae senilis.

Biomechanics of Surgical Implants. The Committee on Biomechanics and Implants, The American Academy of Orthopaedic Surgeons, in this exhibit stressed the biomechanics of surgical implants in the technique of insertion of the screw. Any excessive force needed in inserting the screw means that something is incorrect and the screw should be forced no further. Too small a drill hole leads to splitting of the bone or fracture of the screw. It is recommended that the manufacturer's own drill size be used. The insertion of the screw at an angle will cause a wedging effect and may lead to breaking of the screw. The bending of a plate should be avoided, if this is possible. However, there will be times when a careful, smooth contouring of the plate will be necessary in various operative procedures. The plate, however, should be discarded if it is sharply bent, particularly if this bend occurs at a screw hole. If the plate is inadvertently bent too far and must be bent the other way to straighten it a little, it should also be discarded.

In summary, it was stressed that the surgeon should be sure the fixation device is adequate for the job. Plates, screws, and wires need additional support in the form of casts or traction.

Diagnostic Problems. The Committee on Pathology, The American Academy of Orthopaedic Surgeons, presented an exhibit that was similar to that of recent years except, of course, with different cases. Boxes were set up to display roentgenograms, photomicrographs, photographs, histories, and other pertinent information which would enable one to make a diagnosis. The diagnosis itself and a discussion of the significant points were concealed in a cupboard where they could later be referred to by the observer. The cases which were included this year were:

1. Chondrosarcoma which probably arose in the synovial membrane of the knee and surrounded, but did not invade, the bone;
2. Cavernous hemangioma of the popliteal space which probably arose within the knee;
3. Eosinophilic granuloma of the lower femoral epiphysis;
4. A massive calcific bursitis of the trochanteric region;
5. Osteochondromatosis of the elbow;
6. A huge, benign giant-cell tumor of the sacrococcygeal region;
7. Chordoma of the sacrococcygeal region;
8. Gouty erosion of the anterior surface of the patella;
9. Cavernous hemangioma of the patella;
10. Carcinoma which arose in the epithelized sinus tract and destroyed the tibia.

Coracoclavicular Joint Arthritis. *A Rare Disability.* Dr. John W. Cooper [14].

Bone Tumors. *Analysis of 2,276 Primary Neoplasms of Bone Seen at the Mayo Clinic 1905–1955.* Dr. David C. Dahlin [15], Dr. Ralph K. Ghormley [16], Dr. Edward D. Henderson [17], and Dr. Mark B. Coventry [18] exhibited a detailed study of more than 2,000 cases of bone tumors seen at the Mayo Clinic during

[14] St. Francis Hospital, Honolulu, Hawaii.
[15] Mayo Clinic, Rochester, Minnesota.
[16] Mayo Clinic, Rochester, Minnesota.
[17] Mayo Clinic, Rochester, Minnesota.
[18] Mayo Clinic, Rochester, Minnesota.

the past fifty years. It consisted of actual colored casts of all the basic types of bone tumors and their roentgenographic and microscopic appearances. It classified bone tumors according to their origin and gave the degree of malignant growth of each type, the most common location in which they occur in the body, and the usual age of the patients in whom they occur.

Metals in Surgery. Dr. Albert B. Ferguson, Jr.[19], and Dr. Patrick Laing[20] presented an exhibit which was divided into three portions. The first portion consisted of a description of available metals which included 316 steel, titanium, and zirconium alloys, the tungsten-bearing alloys, and the recently developed stellites and chromium, cobalt, and molybdenum alloys.

The center panel was devoted to the causes of corrosion. This gave a brief outline of some of the causes of corrosion relevant to embedded metals, such as differential aeration, dissimilar metals, metal transference, corrosion cracking caused by inclusions, and damage to the intact oxide layer on which the metal depends for its corrosion resistance.

The third panel showed examples of these causes of corrosion in actual metal implants in patients. The fact that all metal dissolves in the body to some extent was pointed out, and examples of metal failure were given.

The Care of Minor Hand Injuries. Dr. Adrian E. Flatt[21] presented an exhibit which depicted the principles of care given to hand injuries on an out-patient basis in the Accident Department of The London Hospital, London, England.

The exhibit was divided into three main parts: Basic Principles, Methods of Treatment, and Results Achieved.

Basic Principles

The importance of complete records and accurate diagnoses was stressed. Injuries were classified under the following major headings: tidy incised, tidy sliced, untidy, nail-bed injuries, pulp loss, crush injuries, partial amputation, and complete amputation.

Each category was illustrated by a color photograph and a description of the principles of the surgical care. It was pointed out that all injuries cannot be placed dogmatically in one of these categories, but that in most cases the major component of the injury can be so categorized.

Seven essential questions were asked, and it was stressed that no hand injury could be properly treated until these questions had been answered: (1) What is the cut-crush ratio? (2) Is the wound tidy or untidy? (3) Is there any skin loss? (4) Are the tendons injured? (5) Are the bones and joints involved? (6) Is the neurovascular bundle injured? (7) What is the patient's occupation.

Methods of Treatment

The center panel contained a series of color photographs depicting the various stages of the operative care of these eight types of injuries. Most prominence was given to the care of pulp injuries. In these injuries, it is not sufficient to replace the epithelial loss by a skin graft; in order to restore normal function to the finger tips, it is essential to supply fat as a deep cushion to the skin, and, therefore, a thenar flap was advocated for routine use in these injuries.

Results Achieved

The third panel analyzed the results of the application of these methods to nearly 300 consecutive cases of hand injuries seen within one year. Great emphasis is placed on returning the patient to work on the day of injury whenever possible. In the series reported, 85 per cent of the patients were never out of work during treatment. The three most common diagnoses were tidy incised, tidy sliced, and crushed; and the vast majority of the injuries were sutured as primary treatment. Nineteen patients were considered suitable for replacement of skin loss by an immediate split skin graft. In these cases, the graft was sutured in place and the dressings were changed every four days. Of these patients 74 per cent were kept at work throughout their treatment.

This policy was deliberately planned, and in this small series it appeared to be completely justified. No graft failed completely. In one patient there was a small degree of postoperative infection, and in three the grafts were judged to have been less than completely successful.

The degree of recovery was difficult to estimate. Since every single patient was returned to pre-accident employment, it was felt that if they went back to work with no symptoms they should be considered to have recovered completely. On this basis, 96 per cent were considered to have had complete recovery. Of the remainder, in two patients recovery was 50 per cent complete, in six 80 per cent, and in four 90 per cent. This percentage result was judged by assessing the combined anatomical and functional defects of the hand.

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[20] University of Pittsburgh, Pittsburgh, Pennsylvania.
[21] State University of Iowa, Iowa City, Iowa.

The anatomical area liable to trauma will depend on the type of industry served by the individual hospital. The cases reported came largely from the light engineering and woodworking industries, and the areas injured were illustrated by a large hand modelled in proportion to the number of injuries. The gross distortion showed clearly that the index finger was by far the most commonly injured. The middle finger was next in danger, and it was followed by the thumb and little finger. The ring finger was damaged least often, while the hypothenar eminence virtually escaped injury.

Anatomic and Radiographic Studies of the Cervical Spine. A Correlation of Degenerative Changes. Dr. Z. B. Friedenberg [22], Dr. Jack Edeiken [23], Dr. Newton Spencer [24], and Dr. Sinforoso Tolentino [25] demonstrated dry articulated cervical spines, in addition to wet specimens, to show the distribution of degenerative changes. Special emphasis was placed on the relationship of the cord and nerve roots to such reactive bone formation. Most changes were encountered between the fifth and sixth and the sixth and seventh cervical vertebrae. Disc degeneration was seen at these levels in almost half of the forty-one spines examined. The joints of Luschka were frequently involved at these levels, and their proximity to the nerve roots at the entrance to the foramen was shown. Disc ruptures not associated with disc degeneration were infrequent. In each case a roentgenogram was available so that a correlation between the changes seen and their x-ray projection could be studied.

Traumatic Periostitis in Young Children. Dr. Morris S. Friedman [26] presented an exhibit consisting of roentgenograms of several cases of traumatic periostitis in infants and children. The characteristic roentgenographic finding in this condition is a mild to marked periosteal proliferation around the shaft or near the end of a long bone; there is occasionally an epiphyseal separation with extensive periostitis.

In all of these cases trauma was the underlying cause. However, a history of trauma was not always readily obtained. The traumatic episode responsible for the skeletal lesions was often forgotten, considered trivial, or entirely denied by the parents or others caring for the child. Often there was a lapse of time, several days or weeks, from the time of the injury until the roentgenograms were made. It was pointed out that the true nature of the roentgenographic findings in traumatic periostitis is often not recognized by the clinician or roentgenologist. Clinically, or by roentgenogram, traumatic periostitis or "unrecognized skeletal trauma" in an infant or young child may resemble acute osteomyelitis, scurvy, congenital syphilis, infantile cortical hyperostosis, and even malignant bone tumor. Roentgenograms of patients with scurvy, with congenital syphilis, and with Caffey's syndrome were shown to illustrate the resemblance between these disorders and traumatic periostitis.

Traumatic periostitis is a benign affection of relatively short duration and should be differentiated from skeletal lesions of a more serious nature.

Prevention of Automobile Injuries. Dr. Murray E. Gibbens [27], Dr. Ward D. Studt [28], and Dr. William H. Mott [29] showed by means of photographs what can be done in safety engineering of automobiles and driver education to diminish automobile accidents. In 1955, there were 38,000 deaths from and 100,000 people permanently disabled by automobile accidents. A collection of photographs showing some typical accidents were presented, revealing that in many cases the passenger compartment was not badly damaged and that, if seat belts and padding had been used, many injuries and deaths could have been prevented. Rollover bars, stronger car tops, and safety door latches in the locked position would also help to save lives. One panel of photographs called attention to the many sharp projections, points, and edges on the fronts of new cars, which are an obvious hazard to pedestrians. Legislation to control this condition was suggested.

Another group of photographs demonstrated the use of the safety seat belt. Statistics from the Auto Crash Research Department of Cornell University Medical College were presented which showed a 60 per cent better chance of survival, or reduction of injury, from all types of accidents by use of seat belts alone. An improved seat belt with shoulder strap was shown. Testing of seat belts emphasized the need for belts of good quality properly installed into the steel floor or frame of the car. Testimonials of people who believed that their lives had been saved by the belt were shown.

The last panel emphasized the need for better driver education in safe driving techniques. A good driver's code was presented and distributed. Such a code was recommended for use by driver licensing bureaus and as a basis for use of the family car. High-speed driving was re-emphasized as the major cause of highway deaths.

Viewers were urged: (1) to install and use seat belts, (2) to write their automobile manufacturing companies, asking for safety features, (3) to write their state legislatures concerning laws to remove points, sharp

[22] University of Pennsylvania Hospital, Philadelphia, Pennsylvania.
[23] University of Pennsylvania Hospital, Philadelphia, Pennsylvania.
[24] University of Pennsylvania Hospital, Philadelphia, Pennsylvania.
[25] University of Pennsylvania Hospital, Philadelphia, Pennsylvania.
[26] Northern Indiana Children's Hospital, South Bend, Indiana.
[27] Veterans Administration Hospital, Denver, Colorado.
[28] Veterans Administration Hospital, Denver, Colorado.
[29] Veterans Administration Hospital, Denver, Colorado.

blades, and edges from car fronts, (4) to promote driver education in schools, (5) to promote use of a good driver's code by state driver licensing bureaus, and (6) to keep speed down.

Three-Dimensional Anatomy of Haversian Systems. Dr. William H. Harris [30] and Dr. Jonathan Cohen [31].

A Hallacul Ray Plasty — Using Combined Accepted Surgical Principles. Dr. Fred B. Hawkins [32] and Dr. Robert C. Hawkins [33].

The Relationship of the Cervical-Nerve Roots to the Cervical Intervertebral Discs. Dr. Ruth Jackson [34] presented drawings, photographs of roentgenograms, and actual anatomical specimens to show that the nerve roots in the cervical spine do not pass over the intervertebral discs as do the nerve roots in the thoracic and lumbar areas of the spine. The cervical-nerve roots lie directly posterior to the vertebral bodies, which act as safety zones for the nerve roots to protect them from herniation of the intervertebral discs.

The lateral interbody articulations in the cervical spine are the posterolateral boundaries of the cervical discs, and only a relatively small portion of the intervertebral discs are exposed posteriorly. The strong two-layered posterior longitudinal ligament acts as a barrier against extrusion of disc material posteriorly. If a cervical disc ruptures posteriorly, it causes cord compression rather than nerve-root compression.

As the nerve roots leave the spinal canal, they carry with them a dural covering from the dura spinalis. The nerve roots enter the intervertebral canals immediately so that they are never in contact with the intervertebral discs. However, as they enter the canals, they lie between the interbody articulations and the posterior or apophyseal joints. Here they are subject to irritation or compression from any mechanical derangement within the canals.

The lateral interbody articulations are subject to sprain injuries because of their short capsular ligaments. Spur formations develop at the margins of the interbody joints and cause anteroposterior narrowing of the intervertebral canals. These spurs, with their thickened capsular ligaments, have been called "hard discs". However, there is no disc material at this point. Compression of cervical-nerve roots may be relieved by a simple facet fenestration, if one must operate in cases of nerve-root irritation. However, in most cases conservative treatment gives adequate relief of the symptoms without mutilation of the cervical spine by unnecessary surgical procedures.

The Treatment of Benign Giant-Cell Tumors. Dr. J. I. Kendrick [35] and Dr. George S. Phalen [36] showed the site of occurrence of twenty-three proved cases of benign giant-cell tumors. The skeletal diagram pointed out that the tumor most commonly occurs in the ends of long bones. In these twenty-three cases the lower end of the femur and upper end of the tibia were most commonly involved. There were several cases in the upper end of the fibula, outer end of the clavicle, lower end of the radius, lower end of the ulna, lower end of the tibia, upper end of the humerus, and one case in an upper lumbar vertebra, and one case in the proximal phalanx of an index finger. It was pointed out that the benign giant-cell tumor characteristically appears in the third decade of life. The tumor is radiosensitive, and exposure to deep x-ray therapy facilitates complete removal of the tumor. The giant-cell tumor is benign but recurs locally when incompletely removed. The exhibit illustrated four descriptive cases in which treatment had been by preliminary exposure to deep x-ray therapy; ten to twelve months after the x-ray exposure, these tumors had been thoroughly curetted and the defect in the bone had been filled with autogenous-bone grafts. There were two tumors at the lower end of the femur, one at the upper end of the tibia, and one at the proximal phalanx of the index finger. It was pointed out that following exposure to deep x-ray therapy, there is a period of about six weeks during which there is an increase in osteolysis. This is followed during the next seven months by osteogenesis and the tumor fills in with bone; there develops a firm bony wall about the tumor. It is at this stage that thorough curettage is carried out and the defect is filled with bone grafts. In the case shown of the tumor of the upper end of the tibia there was a thirteen-year follow-up; in the tumor of the proximal phalanx of the index finger there was a fifteen-year follow-up; and in the two tumors of the lower end of the femur there was a three-year and a five-year follow-up. Three giant-cell tumors which had been resected were shown. These tumors occurred in the outer end of the clavicle, in the upper end of the fibula, and in the lower end of the ulna. For the tumor of the outer end of the clavicle there was a twenty-year follow-up; for the tumor of the lower end of the ulna there was a three-year follow-up; and for the tumor of the upper end of the fibula there was a ten-year follow-up.

[30] Children's Medical Center, Boston 15, Massachusetts.
[31] Children's Medical Center, Boston 15, Massachusetts.
[32] 2001 Collingswood Boulevard, Toledo 2, Ohio.
[33] Toledo Clinic, Toledo, Ohio.
[34] 3629 Fairmount, Dallas 19, Texas.
[35] 2020 East 93rd Street, Cleveland 6, Ohio.
[36] 2020 East 93rd Street, Cleveland 6, Ohio.

It was concluded that the benign giant-cell tumor is best treated by excision when feasible. Exposure to deep x-ray therapy followed by radial curettage and bone-grafting is effective in selected cases. Preliminary exposure to deep x-ray therapy and the development of a firm, bony wall about the tumor may facilitate surgical excision.

Orthopaedic Aspects of Motor Vehicle Accidents. Dr. Jacob Kulowski [37] presented a series of photographs, charts, and tables to show that orthopaedic interests with regard to motor vehicle accidents parallel those of medicine as a whole, that is, accident prevention, reduction of injuries, improved aids to recovery, and medicolegal rehabilitation. Since the vast majority of injuries come within orthopaedic practice, orthopaedic surgeons ought to be especially alert to opportunities to cut down the increasing annual toll exacted by traffic accidents in life and limb. More specifically, Dr. Kulowski suggested the following fields or areas in which orthopaedic surgeons should be interested:

In the first place, the chief orthopaedic parameter with regard to accident prevention through adequate medical standards of driver licensure is the motor-skeletal fitness of drivers. From this point of view, the chief physical defects seem to be varying degrees of arthritis and congenital anomalies which affect the cervical and lumbar vertebrae. Studies with regard to these and other similar conditions are needed. Dr. Kulowski feels that cervical arthritis may have something to do with producing more than an average number of rear-end and angular collisions at intersections.

The greatest need now is to determine the connections between physical deficiencies, accidents, and injuries. It has been known for a long time that certain physical defects predispose people to greater than chance injuries under force conditions. These include such conditions and diseases as arthritis, osteoporosis, and congenital anomalies and others. The need for ever increasing factors of built-in safety in motor vehicles for all riders because these defects are rather common among the motoring population was stressed. Orthopaedic surgeons might take a more active part in urging their patients to seek vehicles with safety improvements and to urge manufacturers to include them. More detailed studies with regard to the motor skeletal morbidity would be helpful to automotive engineers in achieving maximum safety design.

Dr. Kulowski then stressed the need for improved first aid and emergency treatment, neither one of which is as yet perfectly carried out on the street or in the admitting wards of hospitals. He emphasized, as concerns emergency care, the dual responsibilities of the hospital administration and the medical staff. With regard to definitive treatment, diagnosis was emphasized. There must be adequate consultation services for that group of patients in whom there are multiple injuries (about 55 per cent of the patients). Orthopaedic aims of treatment are early return of function with prevention of undue atrophy and deformity.

About 50 per cent of patients with residual disabilities of the motor skeletal system will require some kind of disability evaluation in the domain of medicolegal medicine; in about 65 per cent of these the neck or low back is involved. Diagnostic pitfalls are chiefly accessory findings which were either present at the time of the accident or which complicated the picture later. In either event, in addition to careful differential diagnosis, a more intimate knowledge of what actually happened during the accident may be very helpful. The greatest single obstacle to orthopaedic differentiation is arthritis.

In conclusion, Dr. Kulowski emphasized the clear need for further understanding and cooperation between physicians, engineers, and attorneys in order to achieve some kind of synthesis and progress in accident reduction, in reduction of injuries, in aids to recovery, and in medicolegal rehabilitation. However, from the standpoint of accident prevention, orthopaedic surgeons can make original contributions by means of further studies of the connection between physical defects and accidents; they should caution patients when disease, medication, cast, brace, or splint may affect driving ability (or rider tolerance to force); they should assist in training programs for licensure examiners; and, when authorized by the patients, they should give information to constituted authority for determination of driver privilege and assist any special examiner in arriving at a sound conclusion regarding the patient's risk on the highway.

Skeletal Manifestations Noted in Sickle-Cell Patients. Dr. Richard W. Leong [38] presented an exhibit based on the study of sixty-one patients with sickle-cell conditions.

The objectives of the exhibit were: (1) to display the types of skeletal changes found in the various groups of sickle-cell conditions and (2) to emphasize the diagnostic problems encountered.

The central attraction of the exhibit was a drawing of a skeleton showing the incidence of involvement of the separate bones and joints and illustrating in detail the gross pathology of the disease in the involvement of a long bone and adjacent joints. The histopathology of the disease was illustrated by means of color photomicrographs from surgical specimens.

The roentgenographic aspects of the sickle-cell diseases in children and adults were shown in a series of skeletal roentgenograms.

Of practical importance to the physician were the skeletal deformities in patients with sickle-cell condi-

[37] 2515 Francis Street, St. Joseph, Missouri.
[38] 2002 Holcombe Boulevard, Houston 31, Texas.

tions and the many diseases simulated by these conditions. The simulated conditions were illustrated by roentgenograms.

Skeletal changes in sickle-cell diseases are the result of two main processes: bone-marrow hyperplasia and circulatory stasis and thrombosis. Skeletal changes in young children are predominantly the result of marrow hyperplasia. In older children and adults, the skeletal picture is a composite of marrow hyperplasia, bone necrosis, and bone sclerosis.

Of the seventeen children with sickle-cell conditions at Jefferson Davis Hospital for whom skeletal roentgenograms were available, only four showed definite bone changes.

The forty-four adult patients at the Veterans Hospital were classified into three groups by electrophoretic hemoglobin studies: 14 per cent of the patients with sickle-cell trait showed definite bone changes, while all of the patients with sickle-cell anaemia and sickle-cell hemoglobin-C disease showed definite bone changes. The patients with sickle-cell hemoglobin-C disease exhibited less severe bone manifestations than those with sickle-cell anaemia. The patients with sickle-cell trait with bone changes showed only mild involvement of the skeleton.

The bones most commonly involved in adults were the femora, the thorocolumbar spine, and the humeri. Bones and joints frequently involved were the pelvis, ribs, shoulders, hips, and tibiae. Bilateral involvement occurred in all patients but two.

Musculoskeletal manifestations may mimic the following conditions: osteomyelitis, syphilis, aseptic necrosis of the hip, osteoblastic conditions, diseases of the spine, enchondroma, osteochondritis dissecans, rheumatic conditions, and neurological conditions such as poliomyelitis, spinal-cord tumor, and spastic cerebral palsy.

Based on the clinical studies, other observations and several recommendations were made.

The Pathology of Brucellotic Osteomyelitis. Dr. Leo Lowbeer[39] presented roentgenograms, photographs, and photomicrographs of cases of brucellotic osteomyelitis and spondylitis in man and animal, together with the case histories. The study was based on biopsies, necropsies, and experimental work. The material consisted of the spinal columns of three patients who died of *Brucella melitensis* infection in Argentina; of the spinal column of one patient who died of *Brucella abortus* infection in Chile; of the spinal column, pelvis, femora, ribs, and scapula of a patient who died of *Brucella suis* infection in Oklahoma; of the spinal columns of three hogs with spontaneous *Brucella suis* infection; and of a variety of infected bones of guinea pigs inoculated with *Brucella suis*. Brucella were cultured in all cases. Brucellosis has been recognized as a chronic granulomatous inflammation caused by any of the three strains of Brucella and involving a variety of organs. In the past, brucellotic osteomyelitis, particularly of the spinal column, has often been diagnosed on a clinical and roentgenographic basis, but because of the low mortality rate and an almost complete absence of biopsy material, nothing has been known about its pathological anatomy and histology except for a few studies based on bone-marrow aspirations.

In all cases of brucellotic spondylitis, human as well as animal, the lesions were found to have a predilection for those portions of the vertebrae contiguous to the intervertebral discs which became secondarily involved and destroyed. The mildest form of inflammation was found in *Brucella abortus* infection, in which the discs were found to be replaced by non-specific granulation and scar tissue with a characteristic tendency to formation of exostoses.

In *Brucella melitensis* spondylitis multiple destructive granulomata were found in vertebrae and adjoining discs, consisting of leukocytes and mononuclear cells in early phases, showing coagulative necrosis and pseudo-abscess formation in later stages and fibrotic encapsulation and osteophyte formation in early as well as late stages. There was a marked tendency to the formation of bizarre foreign-body giant cells. The most extensive destructive lesions were found in the case of *Brucella suis* osteomyelitis, involving the entire spinal column, sacrum, ilium, hip joints, ribs, and scapula. Grossly they vaguely resembled the caseous foci of tuberculosis or syphilis and caused the formation of numerous cold abscesses and sinus tracts persisting for a number of years. In contrast to tuberculosis, however, these lesions were invariably associated with repair and new-bone formation and were microscopically characterized by a mononuclear-cell granuloma undergoing coagulative necrosis in the center and encapsulation at the periphery, with considerable peripheral osteosclerosis. Of particular interest were numerous bone infarcts believed to be caused by toxic, allergic, and vascular phenomena. No tuberculoid nodules were found and giant-cells were rare. In all cases positive cultures were obtained.

Brucella suis spondylitis of hogs was strikingly similar to that of man. *Brucella suis* osteomyelitis of inoculated guinea pigs showed a predilection for ribs and, similar to that of man, was characterized by spontaneous bone destruction and extensive repair.

These studies revealed that brucellotic osteomyelitis is characterized by rapid destruction of bone through granulation tissue composed of predominantly histiocytic cells, containing bizarre multinucleated giant cells and showing a tendency to extensive coagulative necrosis which occurs in melitensis as well as in

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suis infection and involves granuloma as well as cancellous bone and marrow. This granulation tissue becomes rapidly encapsulated by scar tissue, and extensive but incomplete repair with new-bone formation takes place which gives the process its limited destructive and rather stationary character. The resulting lesions have a tendency to remain localized but at the same time active, which is considered a characteristic feature of the brucellotic granuloma. The intracellular parasitism of Brucella, as well as the formation of stationary encapsulated granulomata, is believed to be the cause of this chronicity and of the tendency to recurrence caused by intermittent blood invasion.

The Anatomy of the Brachial Plexus. Dr. J. E. Markee [40] presented an exhibit consisting of thirty transparencies which illustrated most of the significant parts of the motion picture entitled *The Brachial Plexus*.

Some of the scenes illustrated the development of the arm bud which forms adjacent to the position then occupied by the heart at the metameric level of the fourth cervical to the first thoracic nerve. It is in this location of their origin that we see the characteristic innervation of the limb by the brachial plexus. Other scenes pointed out that just as successive areas are innervated serially along the trunk, so are successive areas along the limb bud innervated serially from the fifth cervical through the first thoracic nerve. This orderly arrangement becomes somewhat distorted during elongation of the limb bud. However, the embryonic segmentation maintains its original relationship to the margins of the limb and to the elongated central axis. Consequently at the root of the limb, the pre-axial and post-axial nerves lie farthest apart and are adjacent only in the hand.

Other scenes pointed out that in addition to the cephalad-caudad relationship between skin and muscle and spinal segments, there is also a mediolateral relationship between the location of muscles. The adductors of the extremities are supplied by the more posterior groups of cells in the subsidiary lateral columns; the extensors and abductors are supplied by the more anterior groups.

Other scenes illustrated that different disorders of sensation result from interruptions of the sensory pathways at different levels in the nervous system. Within the peripheral sensory pathways it is of great importance to distinguish among root, plexus, and nerve interruptions. Root lesions result in cutaneous sensory losses in a dermatomal pattern, which frequently contrasts greatly with the distribution of sensory loss in the peripheral-nerve pattern. Similarly, a single anterior-root lesion may cause paralysis of only a certain part of several muscles and may go unnoticed clinically, whereas a nerve lesion may paralyze one or several muscles. It is essential, therefore, to know the segmental or root innervation as well as the nerve innervation of the skin and muscles.

Acute Arterial Injuries: Management in Civilian Practice. Dr. George C. Morris, Jr.[41], Dr. Oscar Creech, Jr. [42], Dr. Stanley E. Crawford [43], and Dr. Michael E. DeBakey [44] presented their experience with 136 acute arterial injuries encountered in civilian practice. A brief account of the history of arterial repair was presented which emphasized the slow acceptance of primary repair as the accepted technique in treatment. Although a successful repair of an arterial injury was performed nearly 200 years ago, suture repair was accomplished in only eighty-one cases in a series of 2,471 acute arterial wounds of World War II. Thus, it was not until the Korean War that primary arterial repair succeeded ligation as the accepted method of treatment. The 136 civilian arterial injuries were divided into four groups: seventy-one transections, fifty-six lacerations, six contusions, and three instances of compression or spasm. In this series, the most commonly injured arteries were the brachial and femoral. Primary repair was performed in ninety-three of these injuries. Restitution of function with good pulses was achieved in 86 per cent of these cases. A homogenous arterial graft was necessary in fourteen patients and amputation followed unsuccessful repair, in seven. Primary repair of acute arterial injuries is the treatment of choice because (1) gangrene in extremities is prevented; (2) pulsatile blood flow is restored and claudication, atrophy, and other trophic changes are avoided; (3) the dangerous sequelae of delayed hemorrhage, false aneurysm, and arteriovenous fistula are prevented. The exhibit presented the four methods of repair which may be necessary in treating these injuries. These four techniques were (1) simple lateral repair of the arterial wound with continuous fine silk, (2) end-to-end anastomosis with continuous fine silk, (3) insertion of a graft, and (4) the use of a long by-pass graft.

Pollicization of the Index Finger. Dr. Robert Q. Murray [45] presented three cases of pollicization of the index finger. Photographs, roentgenograms, and case histories demonstrated the original condition and the late result of replacing the thumb by the index finger. The cases included: (1) traumatic loss of the

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thumb at the level of the base of the first metacarpal, (2) loss of the entire thumb ray and the metacarpal of the index finger, and (3) congenital absence of the thumb, associated with atresia of the radius. Muscles, digital nerves, and digital vessels, except for the digital vessels to the radial side of the long finger, were preserved. The new thumb web was covered by an abdominal pedicle graft. The functional result was considered excellent for each patient; however, cosmetically, the thumb appeared abnormally long.

Muscular Dystrophy. Clinical Aspects, Characteristics, Genetic Factors, and Research. Dr. Melville H. Manson [46].

Intrinsic Internal Fixation in Spine Fusion. Dr. Duncan C. Mc Laughlin [47].

More Education Opportunities for Professional Personnel. Dr. Hart E. Van Riper [48].

Aids for the Orthopaedic Surgeon Working with Crippled Children. Dr. Dean W. Roberts [49] and Miss Jayne Shover [50].

Hip Fusion Using Intramedullary Nail Fixation. Dr. Howard W. Schneider [51] presented a technique of hip fusion with internal fixation between the ilium and femur in order to allow early ambulation of the patient without external support. Six colored drawings were used to show the surgical technique. The Smith-Petersen anterior approach was used. A small counter incision was made over the posterior iliac spine to re-introduce the intramedullary nail after it had been driven in at the acetabulum. An intra-articular type fusion was done and iliac-bone grafts were added. Two skeletal models were used to demonstrate the fixation and position obtained by this method. Roentgenograms demonstrating four representative cases were shown.

The sole fixation device is a curved, four-flanged nail which extends from the posterior iliac spine through the body of the ilium across the hip joint into the medullary canal of the upper two-thirds of the femur. The nail produces six inches of purchase in the body of the ilium and at least twice this length of purchase within the femur. The position of the nail in the ilium utilizes the maximum length of fixation to the strongest part of this bone. Snug fixation is obtained by using the curved, self-cutting type nail, which in itself acts as the cutting instrument in preparing its bed in both the ilium and the femur. The four-flanged shape gives antirotational fixation as well as maximum strength for its weight.

The curved nails are ten, eleven, or twelve millimeters wide, and from forty to forty-eight centimeters long. If the pilot holes are properly placed in the ilium and in the femur, the desired position is consistently achieved. If a straight nail is used, an unsatisfactory position of too much flexion and abduction results. This internal fixation is much more rigid than that obtained by external cast fixation. However, the femur may slide up on the nail with weight-bearing and thus additional contact-compression is obtained.

The postoperative management is surprisingly easy. The patients are able to turn from side to side and to handle themselves in bed with the aid of a trapeze the first few days. They sit up in bed after the fourth day and become ambulatory with the aid of crutches and are allowed partial weight-bearing in six to eight days. A few of these patients are able to discard all support at four weeks.

This is a preliminary report of a small number of cases; therefore, no attempt was made to compare fusion rates with the reported larger series. Twelve fusions have been done. A straight nail was used in the first and curved nails have been used in the others. The first fusion was done over three years ago and the most recent, four months ago. The single failure occurred following the use of a prosthesis in a patient with a neurotrophic joint.

Hip Diseases in Children. Dr. Wayne A. Simril [52] demonstrated, by means of roentgenograms and descriptive legends, the many diverse pathological conditions affecting the child's hip. Congenital and acquired deformities, infections, tumors, osteochondroses, and dystrophic conditions were included.

The stages in the method of treatment for congenital dislocation favored at the St. Louis Shriners' Hospital were demonstrated, as were stages in the progression of the disease process in tuberculosis of the hip and in Legg-Calvé disease. Single examples of multiple other conditions were shown.

Osteoporosis. Post Climacteric; Post Menopausal. Dr. Irving Stein [53] and Dr. Martin Beller [54].

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[47] Memorial Hospital, Houston, Texas.
[48] National Foundation for Infantile Paralysis, New York, N. Y.
[49] National Society for Crippled Children and Adults, Inc., Chicago, Illinois.
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Medullary Nailing of Forearm Fractures. DR. DANA M. STREET [55].

Congenital Absence of the Fibula. DR. T. CAMPBELL THOMPSON [56], DR. L. RAMSAY STRAUB [57], and DR. WILLIAM D. ARNOLD [58] presented an exhibit based upon observation and treatment of thirty-one extremities in twenty-five patients seen at the Hospital for Special Surgery during the years 1939 to 1956. Congenital absence of the fibula is, in fact, an incomplete term used to describe an anomaly which, in its typical form (in approximately 80 per cent of the cases), consists of the following deformities: dypoplasia of the entire extremity, absence of the fibula, anterior bowing of the tibia, equinovalgus of the foot, and anomalies of the tarsal bones and metatarsal rays. The etiology is not known. An accidental injury to the embryo in about the fifth week of life is suspected. No hereditary factor was found in this series. There was no evidence of neurofibromatosis or of pseudarthrosis of the tibia. A tight band of fibrous tissue was found at the site of the absent fibula in most cases. This is believed to represent the anlage of the absent fibula. It is a deforming factor. Following excision of the tight band, the tibial bowing and equinovalgus deformity of the foot were seen to improve in seven extremities observed for from five to fifteen years. Leg shortening has not been affected by this procedure. The treatment recommended in congenital absence of the fibula is resection of the tight band, any release of other tight posterior calf structures at an early age, and elective Syme amputation for cosmetic purposes following closure of the epiphyses if the leg shortening exceeds five inches.

The Histochemistry of Aging Periosteum. DR. EDGAR A. TONNA [59] presented the results of a study of alkaline and acid phosphatase, cytochrome oxidase, and succinic dehydrogenase activity and distribution in the periosteum of rat femora. The animals were divided into groups ranging from the newly born to the aged.

Both the phosphatases and respiratory enzymes were found to be in greatest abundance at the osteogenic layer of the periosteum in animals of all age groups. The greatest enzyme activities were noted at a time comparable to maximum bone formation in the rat. Although some fluctuation in the activity of the phosphatases was noted from one age group to another, it was maintained at quite a high level even in the oldest animals studied. On the other hand, the respiratory enzyme activity was very intense during the period of maximum bone formation and then, within a three-week period, dropped critically to a very low level and remained there throughout the life of the animal.

Since the level of the activity of phosphatases remained high throughout the different ages studied, changes in rates of bone development and repair could not be attributed to these enzymes. The respiratory enzyme changes observed, however, point to an important relation between these enzymes and bone chemistry. Previous investigators have revealed the association of respiratory enzymes with the mitochondrial complement of cells. It is believed, therefore, that the mitochondria are intimately involved with the processes of bone formation, growth, and, possibly, repair.

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AMERICAN SOCIETY FOR SURGERY OF THE HAND

The Twelfth Annual Meeting of the American Society for Surgery of the Hand was held in Chicago under the Presidency of Dr. Lot D. Howard, Jr., of San Francisco, California.

On January 25, 1957, the following papers were read:

Restoration of Finger Function by Tenodesis in the Hand Paralyzed by Poliomyelitis. Dr. C. Edwin Irwin [1] and Dr. James C. Wray [2] presented an interesting paper on the role of tenodesis in the surgical reconstruction of the hand paralyzed by poliomyelitis. The authors pointed out that extension of the wrist causes secondary flexion of the fingers by increasing the distance between the origin of the long flexors and their insertion, and that, conversely, flexion of the wrist may extend the fingers as a natural result of increasing the distance from the origin of the extensors to their insertion. Using this principle, the authors believe that the tenodesis procedure can be accomplished by one of two methods: (1) a static tenodesis in which the tendon mass is inserted into the bone, or (2) a dynamic tenodesis, in which the tenodesis effect is produced by transferring an actively contracting muscle into the tendons of the paralyzed muscles with enough tension in the transfer to produce a tenodesis effect.

The authors felt that the static tenodesis procedure should be reserved for patients who lack sufficient muscle motors for conventional transfers. In order for a tenodesis to function properly, the patient must possess a mobile wrist as well as mobile fingers and elbow flexion. In addition, forearm supination and pronation would be desirable, but not absolutely necessary. While an active wrist extensor greatly enhances the value of a flexor tenodesis, it was felt that in the absence of an active wrist extension, the wrist could be made to fall into an extended position by active supination of the forearm and flexion of the elbow. The grasp which results, according to the authors, is very slight; but an effective hook is created which the patient may utilize to great advantage.

It was emphasized that tenodesis of the long extensor tendons will not fully extend the fingers unless active intrinsics are present; however, finger extension may be improved in this instance by a flexor tenodesis which stabilizes the metacarpophalangeal joints. Of particular interest was the method utilized by the authors in anchoring the profundus tendons to the radius. This method was to pass No. 28 stainless-steel wire through the tendons through small drill holes on either side of the radius, and out through the skin on either side of the forearm. This wire was pulled out as soon as union had occurred between the tendons and the raw bone. Four cases were presented in detail, illustrating the various approaches to this problem.

Dr. Richard Miller [3], in discussion, re-emphasized the point made by the authors that the tenodesis principle, rather than wrist fusion, should be used to achieve function of the hand. He also pointed out that this particular principle could be used in problems other than poliomyelitis with success and that even in muscle distrophy there might be some indication for the procedure.

Dr. Paul R. Lipscomb [4] was critical of the use of the term *dynamic tenodesis*, feeling that it should be replaced by the words *tendon transfers*, since tenodesis, by definition, means suturing of the proximal end of a tendon to the bone. He agreed wholeheartedly with the authors that tenodesis was preferable to fusion of the wrist and that the most important action in the function of the hand is extension of the wrist.

Tendon Grafts in Children. Dr. Lee Milford [5] reviewed nine cases of tendon grafts in children done at the Campbell Clinic. He pointed out that there are differences in the grafting of free flexor tendons in children and in adults.

The author stated that the optimum age for flexor tendon grafts is probably between seven and fourteen years of age. After fourteen years of age, the hand rapidly takes on the qualities of an adult hand with slower healing powers and increased production of undesirable scar tissue. Between seven and fourteen years of age, there is less scar production and cooperation can usually be obtained. Before seven years of age, cooperation cannot be depended upon; splinting during the postoperative period is more difficult, and the surgical technique, in dealing with the minute structures, is more difficult.

The author felt, in spite of these disadvantages in very young children, that good end results can still be expected for four reasons. First, the tendon injury encountered in a child is usually a laceration resulting from either a knife or a broken bottle and is not usually accompanied by crushing or severe contamination of tissue as is frequently seen in the adult. Second, complete passive joint motion is nearly always maintained because of the substitution habit of a child who will ride down the injured finger into flexion by the adjoining fingers. Third, in a child the caliber of the free graft is smaller and it can, therefore, be revascularized more rapidly with less chance of necrosis within the center of the graft. Fourth, the child's growth is another advantage. It is the author's impression that, should the tendon graft be made too loose during surgery, the

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tension will slowly be increased as the longitudinal growth of the forearm bone takes place. If the graft is too tight, the muscles will gradually compensate by growing and stretching.

Points of technique were discussed and illustrated with slides. It was stressed that although immobilization is maintained with plaster, complete immobilization is difficult to obtain. This is particularly true in very young children.

There was an adequate follow-up in seven children. Four had good results; the involved finger tips could be brought to within one-half inch of the mid-palmar crease. One child had a fair result, and in two others the results were poor.

A motion picture was presented showing the results obtained in four of the patients.

DR. J. ROBERT COCHRAN [6] discussed Dr. Milford's paper and agreed that repair should be done as early as possible. He complimented Dr. Milford for having thoroughly covered the subject. He mentioned the surprising ease with which an infant can free himself from what is thought to be a secure dressing. He said that he frequently uses a plaster cast which hooks, not only around the elbow, but also around the chest. Dr. Cochran also felt that in small children and infants the use of 00000 chromic catgut for closure of the skin is valuable, since it obviates the necessity of removing sutures.

DR. STERLING BUNNELL [7] reported the results of seventy-four tendon-grafting procedures done in young people. The results were very good in thirteen, good in thirty-eight, fair in nineteen, and poor in four. Dr. Bunnell agreed with Dr. Milford that, on the whole, the results obtained in children are better than in adults. Growth tends to improve the function of an extremity. A muscle, in growing, will compensate in three to nine months for the tendon being too tight or too loose. However, he pointed out that one should always strive for normal tension. Dr. Bunnell agreed with Dr. Cochran as to the use of catgut for the closure of the skin in a child.

Flexor Tendon Injuries of the Fingers and Thumb. DR. ALBERT VAN'T HOF [8] and DR. KINGSBURY G. HEIPLE [9] analyzed the results in their series of sixty flexor tendons which had been repaired primarily; twenty-one of these were in the thumb, and thirty-nine were in the fingers. Sixteen of the tendons which were repaired were within the flexor tunnel in the fingers and twenty-three were in the palm. All were treated by primary repair of the injured flexor tendons. All of these injuries except two were repaired by the Bunnell wire technique. The flexor tendons in these two patients were outside the flexor tunnel and were repaired with silk. The flexor sublimis tendons, when severed, were cut short, and the fascial tunnel was incised or completely removed over the lacerated tendon. The pull-out wires were removed at the end of three weeks, and active motion followed. In order to compare statistically their results with results of others, the authors collected a group of three hundred and ten cases of hand injuries, one hundred and eighty-five of which were repaired in the flexor tunnel, thirty-two repaired outside the tunnel. On the basis of Dr. Boyes' tests of function, that is, the ability of the injured finger to flex to the distal palmar crease, this series of cases was compared statistically with those which had been reported by Dr. Boyes in 1950, as well as with a series of primary tendon grafts reported by Dr. Flynn in 1953. The authors concluded that graphic comparison of the series of primary repairs with the series of tendon grafts indicated that grafts within the flexor tunnel gave distinctly better results than the results of primary repair. They also felt that these statistics indicated that grafting procedures were preferable in the treatment of injuries within the flexor tunnel. They concluded that the results of primary repair outside the flexor tunnel and of the flexor pollicis longus are better than the results of repair of the flexor tendons within the tunnel. They suggested, since there is a shorter period of disability in primary repair of flexor tendons which are injured outside the tunnel and within the thumb, that these areas continue to be treated by primary tendon repair.

DR. JOSEPH H. BOYES [10], in discussing this paper, complimented the authors on their clear and concise presentation of the problem. It was Dr. Boyes' feeling that the authors' series of sixteen cases which were repaired in the flexor tunnel (43 per cent of these lacked one and one-half inches of flexing to the distal palmar crease) should be compared, not with the series of tendon grafts which he had presented in 1950, but with a group of consecutive repairs performed in the last year by Boyes and Wilson. In this group, 25 per cent flexed completely, and all flexed to within one and one-half inches of the distal palmar crease. Dr. Boyes was critical of primary tendon grafts; it was his feeling that if an infection developed in the wound in the presence of a tendon graft, the surgeon had probably "burned all his bridges behind him" since there was little chance of ever obtaining a functional result by a secondary procedure. He also pointed out that the results in the series of primary tendon grafts reported by Dr. Flynn were not superior to those obtained by secondary grafting.

DR. J. LEONARD GOLDNER [11] used the example of trigger-finger to emphasize the fact that a small amount of swelling of the flexor tendon could limit the injured finger flexor where it passes beneath the fibrous annular

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[10] 1401 South Hope Street, Los Angeles 15, California.
[11] Duke Hospital, Division of Orthopaedics, Durham, North Carolina.

ligament. It was his feeling that one should do primary tendon repair in the palm only when the flexor tendons had been lacerated with the fingers in extension, in order that the repaired flexor tendon would not lie beneath the fibrous pulley at the metacarpophalangeal-joint level in any position of flexion or extension. He also felt that one could repair the flexor profundus tendon by a suture or advancement when lacerated, only, distal to the insertion of the flexor sublimis tendon in the area distal to the fibrous flexor sheath over the distal interphalangeal joint. He believed that there was considerable latitude for error in the end result in instances of laceration of the long thumb flexor, and here, a primary tendon repair could be attempted in the thumb area where the flexor tendons are enclosed within the fibrous tunnel. Dr. Goldner felt that tendon-grafting was the procedure of choice for laceration of the flexor profundus and sublimis within "no man's land".

The Problem of Collagen Diseases. Dr. William E. Ehrich [12] discussed collagen diseases. This group of maladies is characterized by widespread involvement of the collagen fibers and includes rheumatic fever, rheumatoid arthritis, lupus erythematosus disseminatus, generalized scleroderma, dermatomyositis, polyarteritis, and serum sickness. An interesting and fundamental discussion of the normal structure and function of the connective tissue was presented. The pathological processes which occur in the collagen diseases fall into two categories, degenerative and inflammatory. The degenerative lesion is known as mucoid degeneration, and the inflammatory lesion as serous, fibrinoid, and granulomatous inflammation. These changes were discussed in relation to the pathological and chemical changes which occur. Some excellent slides were presented in illustration. Dr. Ehrich finally discussed the various theories in pathogenesis. The three main theories which deserve consideration are: (1) Selye's theory that they are diseases of adaptation to chronic stress, (2) the author's theory that they are dysgammaglobulinaemias, and (3) Klinge's theory that they are allergic diseases. No definite conclusions were reached as to the etiology of these diseases.

Dr. Harvey E. Billig, Jr.[13], congratulated Dr. Ehrich for his pioneer studies in collagen diseases. Agammaglobulinaemia was discussed and it was pointed out that homologous tissue transplants, that is, skin grafts, will take in the presence of agammaglobulinaemia.

Dr. S. Benjamin Fowler [14] congratulated Dr. Ehrich on his presentation.

The Extensor Mechanism. Dr. Joseph Markee [15] presented a motion picture showing special dissections of the extensor apparatus of the finger in autopsy material and in fresh specimens, as well as drawings and animated cartoons in order to amplify the anatomical dissections. This was a beautiful presentation and showed the intricate anatomy and function of this area based on over 100 anatomical dissections.

Diseases of Fingernails: Clinical and Histological Findings in 659 Cases With Therapeutic Notes. Dr. Cleveland J. White [16] discussed diseases of fingernails and summarized the clinical and histological findings in 659 cases of pathological conditions in fingernails. He showed slides of many of these conditions. Surgery is seldom indicated in diseases of the nails. Exceptions to this occur in the presence of acute infections, malignant conditions, underlying osteomyelitis, and certain grossly deformed nails. Tumors can usually be recognized by their appearance and biopsy is indicated.

Dr. White stressed the importance of a biopsy made from the nail plate. Histological study of the material obtained yielded an exact diagnosis in 80 per cent of his 659 cases. An ordinary nail clipper is used to obtain the material, and the procedure is, of course, completely painless. Infectious conditions, such as ringworm, deep fungus infections, and bacterial infections, were discussed. Many other conditions of the nails resulting from contact with chemical agents, eczema, and hypovitaminosis were discussed, and therapeutic methods set forth.

Dr. S. Baron Hardy [17] commended Dr. White for his large and varied series of cases. He agreed that conservatism is indicated in surgery of the nail, particularly in the presence of infections. He feels that in suitable patients it is possible to do nail-grafting by using a section of another nail as a graft.

Dr. William Metcalf [18] mentioned some points of technique in the treatment of damaged nails, in particular, injury to the nail matrix, and stated that the matrix should be debrided and repaired. Secondary repair of a nail bed is occasionally indicated.

Sporotrichosis. A Report of Twenty-Three Cases in the Upper Extremity. Dr. Robert J. Duran [19], Dr. Mark B. Coventry [20], Dr. Lyle A. Weed [21], and Dr. Robert R. Kierland [22] presented

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twenty-three cases of sporotrichosis which was localized in the upper extremity. The incidence was highest in housewives, farmers, and florists, and seemed to occur primarily as a result of the handling of plants by persons with abrasions of the skin, and also as a result of puncture wounds of the skin of the hand. The primary lesion was followed by secondary nodular and ulcerative lesions ascending along the lymphatic channels of the upper extremity. The authors pointed out that it was rare to establish the diagnosis by culture obtained by a mere swabbing of the lesion. They recommended biopsy of the lesion and maceration and culture of the specimen. The authors were able to make the diagnosis by a simple stained biopsy specimen in many instances. They recommended an aqueous saturated solution of potassium iodide, orally, in treatment of the localized lymphatic type of sporotrichosis. All of their patients had responded well. Treatment was continued for four to six weeks after apparent recovery.

Dr. Michael L. Mason [23] and Dr. Carroll O. Adams [24] discussed the paper. They complimented the authors on their presentation. Both emphasized the importance of the recognition of this condition and the need for keeping it constantly in mind when treating hand infections and hand injuries. Both discussors considered that it was not as rare a clinical entity as had been thought.

Electrical Burns of the Upper Extremity. Dr. G. Kenneth Lewis [25] presented an interesting discussion of burns of the upper extremities and of shock resulting from contact with electric current. He pointed out that one of the primary characteristics of electrical burns is their tendency to progress beyond the visible injury seen immediately after the accident. The appearance, markings, progression, and other characteristics of electrical burns are in many ways different from thermal injuries. It is nearly impossible to know accurately the degree of injury following such a burn. The vessels of an extremity are particularly vulnerable and extensive damage may result in hemorrhage and late thrombosis.

The author described the range in importance of electrical burns and the amount of current, resistance, the path of the current, duration of contact, and the individual susceptibility relating to these injuries.

The emergency treatment of severe electrical injuries was discussed. The author pointed out that there is a difference of opinion as to the time for definitive treatment of non-fatal burns. He was of the opinion that an early conservative therapeutic approach is important. The initial examination does not permit an accurate estimate of the extent of injury. This sometimes cannot be determined for days or even weeks. Nevertheless, Dr. Lewis said that as quickly as the complete extent of destruction can be accurately ascertained, definitive repair should be instituted and accomplished. He stressed the use of split-thickness grafts, full-thickness grafts, and pedicle flaps.

Slides of several cases were presented, and the techniques and procedures employed by the author were reviewed.

Dr. H. Minor Nichols [26] congratulated Dr. Lewis on his study of the effects of electrical current on living tissue. He stated that he had seen a number of instances of severe electrical burns among linemen working with seven-thousand-volt current. These burns were extremely destructive, and most of the patients needed pedicle grafting. Dr. Nichols stated that on a few occasions he had attempted to save the deep tissues by using an early pedicle graft to cover nerves and tendons of doubtful viability. He found that nothing was gained by this maneuver, and he now prefers conservative treatment until the extent of the damage can be determined.

Dr. J. William Littler [27] stated that electrical burns are among the most severe injuries to the hand and forearm that he has seen. He feels that only when the devitalized tissues have been eliminated, danger of hemorreage past, and the wound healed with either free or pedicle skin grafts, can a program of further functional rhstoration be considered. Many of these injuries are from the first so far beyond the point of no return that early amputation must be considered.

Surgical Reconstruction of the Upper Extremity Paralyzed by Poliomyelitis. Dr. Edwin R. Schottstaedt [28], Dr. Loren J. Larsen [29], and Dr. Frederic C. Bost [30] presented a comprehensive discussion of the basic principles involved in muscle transfer, particularly when an entire muscle is detached from its origin and insertion, leaving intact the neurovascular pedicle, the muscle being transferred to a new position for function. The authors discussed the methods of giving power to the finger flexors by tendon transfers and by the principles of tenodesis, as well as methods of obtaining interosseus action by tendon transfer. They described a unique method of splitting the head of the metacarpal with an osteotome, increasing the curvature of the head of the metacarpal in a dorsovolar plane, and inserting a small wedge of

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[25] 6 North Michigan Avenue, Chicago 2, Illinois.
[26] 232 Medical Arts Building, Portland 5, Oregon.
[27] 14 East 90th Street, New York 28, N. Y.
[28] 384 Post Street, San Francisco 8, California.
[29] 384 Post Street, San Francisco 8, California.
[30] 384 Post Street, San Francisco 8, California.

bone as a bone block to maintain the spread of the head of the metacarpal. This allows the base of the phalanx to butt against the head of the metacarpal when the fingers are extended by the long extensors as a result of the bone block, limiting the degree of extension of the metacarpophalangeal joints to slightly less than 180 degrees. Tendon transfers for pronation and supination of the forearm were discussed; they included a shift of the biceps insertion to the side of the radial tubercle opposite its normal insertion, as well as a transfer of the pronator teres insertion to the opposite surface of the shaft of the radius. In this way, pronation on the part of the biceps transfer and supination on the part of the pronator teres transfer could be obtained. The authors pointed out that active supination can be successfully gained by use of the palmaris or the flexor carpi ulnaris redirected dorsally to the shaft of the radius, with the tendon or the transplanted muscle being led around the ulna rather than between the radius and ulna. Elbow motion would best be provided by the Steindler flexoplasty if a suitable muscle mass was present.

In the absence of this, they have used a pectoralis major transfer or a triceps transfer to provide elbow flexion. Also the latissimus dorsi has been used as transfer. The sternocleidomastoid muscle, if transferred to the biceps, produced elbow flexion, but it was weak. The authors' use of the pectoralis major muscle transferred on a neurovascular pedicle for replacement of the anterior and central deltoid muscle was excellent. This procedure was of particular value when a small portion of the posterior deltoid was still present. The superior edge of this muscle transfer was sutured as near as possible to the superior nuchal line and the cervical spinous processes, and the inferior edge was carried as near as possible to the deltoid mid-line, and the insertion of the pectoralis major was left undisturbed.

Dr. Leo Mayer [31] complimented the authors on their presentation and their excellent results. He was particularly pleased about the method of opening the metacarpal head in order to prevent clawing from interosseus paralysis when long extensor tendons were present and active. He emphasized the need for some slight action present in the posterior deltoid muscle when transfers for deltoid action are performed. If a portion of the posterior deltoid was present, a good result could be obtained by transferring the trapezius muscle to provide deltoid action. It is also important, in obtaining the abduction of the shoulder by tendon transfer, that enough of the short rotator cuff muscles are present in order to hold the head of the humerus in place in the scapula.

Dr. C. Edwin Irwin [1] re-emphasized the importance of the wrist in tendon transfers for finger flexion. He said that he prefers Eyler's modification of the Steindler flexoplasty, in which the flexor sublimis, the pronator teres, and the palmaris longus muscles are used, excluding the flexor carpi ulnaris muscle.

Mallet-Finger. Classification and Methods of Treatment. Dr. Donald R. Pratt [32] discussed mallet-finger deformity resulting from injury of the insertion of the extensor tendon of a finger. Seventy-five consecutive cases were reviewed and classified as to the type of trauma responsible for the injury.

Correct splinting is essential to a good result and involves slight hyperextension of the distal joint and moderate flexion of the middle joint of the finger. Early splinting in this position for five weeks will preserve the function. Splinting in this position by the use of external splints is difficult. Plaster of Paris correctly applied can be used successfully, but it is cumbersome and awkward. The author prefers an internal splint of a longitudinal stainless-steel Kirschner wire of medium caliber. This type of splinting was used in all of the seventy-five cases in this series. In thirty-nine cases, a guide consisting of a metal bar with three adjustable points of pressure to hold the finger was used to insert the Kirschner wire. The ends of the wire are cut off short beneath the skin, and the patient is comfortable during the period of the splinting.

Differences in method of treatment in individual cases depend on the time interval since injury, the age of the patient, and the presence or absence of a fracture. Some of the details of the technique of repair were discussed. Useful motion was restored in the majority of cases. More motion in the distal joint was obtained in the younger age groups. Fractures complicated the functional recovery but, when reduced, were a minimal factor. No joint damage or loss of function has resulted from the use of the Kirschner-wire internal splint. It is felt that the guide has been a very important adjunct in the proper placement of the internal splint.

Dr. Sterling Bunnell [7] discussed this paper and emphasized certain points made by Dr. Pratt. He feels that internal splinting has definite advantages over any other type of splint and that the guide is of definite value.

Dr. S. Benjamin Fowler [14] believes that the use of an internal splint is not necessary. He feels that if one is used, it should splint only the distal joint of the finger, and that the middle joint can be immobilized successfully by tape or with plaster. In most cases, he feels that plaster is a sufficient splint.

Dr. J. Edward Flynn [33] said that he prefers a simple external splint.

Dr. Joseph T. Moreau [34] discussed the use of the internal splint and of the guide. Dr. Bunnell had asked that he discuss the paper since he is the inventor of the guide. Dr. Moreau agreed with Dr. Pratt concerning the use of the Kirschner-wire splint and believes that the guide has greatly simplified the procedure.

[31] 1150 Fifth Avenue, New York 28, N. Y.
[32] 516 Sutter Street, San Francisco 2, California.
[33] 475 Commonwealth Avenue, Boston 15, Massachusetts.
[34] Le Marchand Mansion, Edmonton, Alberta, Canada.

The Annual Business Meeting was held at 4.30 P.M., January 25, in the Palmer House.

The Annual Dinner for members and invited guests was held on the evening of January 25, at the Palmer House.

The Clinical Program for members and invited guests was presented on the morning of January 26, at the Palmer House. The following papers were presented:

A Minor Hand Surgery Service. DR. ADRIAN E. FLATT [35] described the development and progress of a minor hand injury service at The London Hospital during the last few years. This is a large teaching hospital, and one of the major objectives of the service is to train undergraduate and postgraduate students. The service functions in the out-patient department and the term *minor* is merely a means of distinguishing injuries that can be treated on an out-patient basis from those which require hospitalization.

A prime objective of the service has been to standardize the method of diagnosis and treatment. The use of cards is stressed as a teaching aid in both diagnosis and treatment.

Operative techniques stress respect of tissues and their dislike of being sutured or bandaged under pressure. Fine instruments and, in general, non-absorbable monofilament sutures are used. Buried catgut is discouraged. Anaesthesia is by local block. Dressings are restricted to a minimum, and early mobility is encouraged. Rigid immobilization is not used unless absolutely necessary and, when indicated, malleable aluminum strips padded with rubber are used. Plaster of Paris is never used.

A total of 292 patients were seen during a period of one year. A careful analysis of these cases was reported. Excellent results had been obtained. This was evidenced by a high rate of complete recovery of function, a limited amount of time lost from work, and rapid healing with a minimum of infection. Eighty-six per cent of the patients were never out of work following their injury. This would seem to be a particular triumph when one considers the benefit schemes available to workers in England and the tradition of disability prevalent among workers there.

DR. CONDICT CUTLER [36] complimented Dr. Flatt on his excellent results. He questioned, however, whether such a plan was applicable for general use in the training of residents. He raised certain questions which he felt presented hazards. These related to the amount of responsibility which can be delegated to residents and to the amount of freedom that should be permitted residents in handling hand cases.

Dr. Flatt, in closing, stated that the average house officer in England has been in training longer than the average resident in the United States; he felt they could be allowed more latitude in treatment.

Radial Styloidectomy and Bone-Peg Graft for Non-Union of the Carpal Navicular. DR. SAMUEL G. STUBBINS [37] and DR. J. GEORGE FUREY [38] presented an interesting group of eight patients in whom there was non-union following fracture of the navicular bone. Most of these patients were treated by resection of the radial styloid process and grafting of the fractured navicular bone. The duration of non-union in these patients ranged from nine months to fourteen years.

Following the bone-grafting the wrist was immobilized for two to seven months. Only one patient in the group was dissatisfied with the end result. All of the patients obtained good bone union following bone-grafting. The average period of immobilization was 4.3 months. Bone-grafting was done in seven patients in the series; in one patient a styloidectomy was performed and a small proximal navicular fragment was excised. This group of cases constituted a selected series which presented the following prerequisites:

1. Non-union;
2. Symptoms severe enough to interfere with the patient's work or pleasure;
3. Both fragments of bone were approximately of equal size and large enough to allow purchase of the bone graft;
4. Absence of objective evidence of degenerative change in the other carpal bones.

DR. CARRUTH J. WAGNER [39] complimented the authors on their excellent series of cases. He said that in his own group of unselected cases (thirty-eight patients), there was a 30 per cent incidence of failure. He considered, since the navicular was a connecting rod between the proximal and distal carpal bones, that simple radial styloidectomy was not enough in instances of non-union. Dr. Wagner emphasized his belief that the more one studied this problem, the less sure of any axiom one became. The resection of the radial styloid process gives an excellent exposure and operative approach to the fracture for the purpose of bone-grafting. There was a 20 per cent incidence of aseptic necrosis in Dr. Wagner's patients with fracture of the navicular.

The Restoration of Function of the Hand in Patients with Quadriplegia. DR. PAUL R. LIPSCOMB [4] described his experience at the Mayo Clinic during the past twenty months with nine quadriplegic patients who had lesions of the cervical portion of the spinal cord between the sixth and seventh cervical

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[36] 620 Park Avenue, New York, N. Y.
[37] 10515 Carnegie Avenue, Cleveland 6, Ohio.
[38] Veterans Administration Hospital, Parma, Ohio.
[39] United States Public Health Service Hospital, San Francisco 18, California.

vertebrae. All of these patients had sufficient strength in the extensor carpi radialis longus, the extensor carpi radialis brevis, the brachioradialis, the flexor carpi radialis, and the pronator teres of at least one upper extremity to warrant the tendon transfer. In four of these nine patients, strength was such that bilateral transfers could be performed.

The surgical procedure was carried out as a two-stage operation which was performed under light general anaesthesia. This was considered preferable to a brachial block. By the use of this technique, active extension and flexion of all digits, the correction of clawing, and the opposition of the thumb were accomplished. These tendon transfers utilized the function of automatic motion of the fingers that accompanies movements of the wrist. Arthrodesis of the wrist rarely, if ever, should be done in patients who have quadriplegia.

The author stated that patients in whom such tendon transfers are done regain the functions of light pinching and grasping. They are able to discard special appliances for their hands and become more independent. He stressed the importance of having their postoperative rehabilitation conducted by competent physical therapists.

Diagrams and charts were shown illustrating the exact technique employed, and a short motion picture demonstrated some of the results obtained.

Dr. James N. Wilson [40] stated that in some cases of injury to the spinal cord at the sixth and seventh cervical level, the only functioning muscles available for transfer in the forearm are the radial wrist extensors, the pronator teres, and the brachioradialis. He said that when both radial wrist extensors are strong, it is safe to use the extensor carpi radialis longus to provide flexion of the fingers. Extension of the fingers and the thumb can be provided by tenodesis.

Restricted Traumatic Ischaemic Contracture in the Hand: Prophylactic Treatment. Dr. Carl E. Nemethi [41] presented an interesting review of his approach to the acutely injured hand. This is a method of local treatment of the wound which results in minimal damage to the dorsal venous plexus at the time of surgery. The author recommended the local injection of hyaluronidase into the traumatized hand at the closure of the wound, 600 to 800 units being used for the hand itself, or 150 to 200 units when the fingers only are injured. In addition, the author pointed out the need for using a type of pressure dressing for the hand which applies slight pressure over the fingers, but with an absence of pressure at the wrist where the dorsal venous plexus crosses. The author used a stockinette bandage as the outer wrapping over a fluff type of dressing, and at the wrist level it was applied loosely enough to enable the surgeon to insert two fingers beneath the dressing. The author had been impressed with the minimal pain which his patients experienced postoperatively with this dressing even in severe crushing injuries, as well as with the early motion which they were able to achieve. It was the author's belief that hyaluronidase contributed to dimunition of the oedema and lessening of the pain. As a result of the combination of the local therapy and the type of dressing which was applied, ischaemic contracture was prevented.

Dr. Raymond M. Curtis [42], in discussing the paper, complimented the author on an interesting presentation. He felt that the author's results warranted further investigation into the local use of hyaluronidase in order to further determine its value, and he agreed with the author's emphasis that proper application of a dressing to the hand is most important, for he also felt that much damage is done to the injured hand by the pressure of an improperly applied, excessively constricting dressing.

Dr. Harold E. Crowe [43] said that he had seen several cases of the type that Dr. Nemethi discussed, that is, the crushed hand or the eviscerated hand, which, at the end of twenty-four hours, showed relatively little swelling and quite free motion. The patients were discharged from the hospital without taking any narcotic medication with them. This, to him, was a new experience and led him to believe that Dr. Nemethi's approach should be taken seriously.

Dr. William T. Medl [44] said that in 1949 therapy with ACTH was first used in crushing injuries of the hand. He stated that it limits oedema and the reaction to hematomata. Since intravenous hydrocortisone has become available, he starts the therapy with 100 milligrams of this in addition to ACTH. The patient's pain is greatly diminished and the oedema is limited or disappears, as it did in the hands injected with hyaluronidase.

In closing, Dr. Nemethi said that he agreed with Dr. Curtis that the term *pressure dressing* should not be used, since the average practitioner who sees many hand injuries primarily may have a different concept of pressure dressing. *Compression dressing* might be a better term, thus indicating a limited amount of correctly applied pressure.

Metastatic Tumors of the Hand. Dr. Robert Kerin [45] had reviewed the literature on metastatic

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[41] 3719 West Vernon Avenue, Los Angeles 8, California.
[42] 2919 St. Paul Street, Baltimore 18, Maryland.
[43] 635 South Westlake Avenue, Los Angeles 57, California.
[44] 111 East 71st Street, New York 21, N. Y.
[45] Veterans Administration Hospital, Cleveland, Ohio.

tumors of the hand and was able to find a total of only twenty-three cases. These cases were briefly summarized. It was noted that the terminal phalanges were the most commonly involved, and the middle and proximal phalanges less commonly. Metacarpals were occasionally involved, but there was no recorded instance of involvement of the carpal bones. Males were afflicted twice as often as females. In approximately 50 per cent of the patients the primary neoplasm was in the lung. The presenting complaint of a metastatic malignant growth in the hand was most often that of an acute inflammatory lesion. The lung is the most common primary site of origin, and other primary sites include the breast, the kidney, the uterus, the bladder, the parotid gland, the testicle, the colon, and the prostate.

The roentgenographic and histological aspects of this disease entity were presented and the differential diagnosis was discussed.

The author presented six new cases of metastatic tumors of the hand. The primary lesion was in the lung in two patients, and, in one patient each, in the kidney, the breast, the adrenal, and the skin of the toe. In three of these six patients, the secondary lesion in the hand was the presenting complaint. This was also frequently noted in the cases collected from the literature.

Dr. Kerin feels that one of the reasons for the paucity of reports in the literature is that the hand generally is not included in skeletal surveys and, therefore, the lesion, if it does exist, is not recognized.

Dr. Robert E. Carroll [46] stressed the importance of the roentgenogram in the diagnosis. He also mentioned the importance of having tissue examined by the pathologist. If a metastatic tumor is found, he believes an amputation of the phalanx, ray, or, rarely, the entire hand may be the best way of treating the problem.

Dr. Joseph L. Posch [47] discussed the rarity of these metastatic lesions. He reported that he had surveyed the records of two large Detroit hospitals and had been able to find no cases.

Dr. J. Edward Flynn [10] reported that he had seen one patient in whom the primary lesion occurred in the lung.

Management of the Burned Hand. Dr. D. C. Robertson [48] outlined a technique of management of the burned hand. The immediate method of dressing of the hand consisted in an application of petrolatum covered by dressing pads, and the hand was immobilized on a universal type of splint. The initial dressings were left in place for eleven days, and at the time of the first dressing change a minimal amount of surgical debriding of the obviously necrotic tissue was carried out. Dry dressings were then applied if the surface of the wound was moist, or if the wound was dry, it was dressed with petrolatum and gauze pads. Forty-eight hours later another dressing was applied using the same technique of minimal débridement; this dressing was applied under anaesthesia. By the eighteenth day, four dressings with débridement had been carried out. At this time, the burn wound was found to be ready for grafting; a split-thickness skin graft, .08 to .010 inch in thickness, was used. The grafts were not sutured in place but were simply immobilized by pressure dressings.

The author considered that the open method of treatment, while suitable for other parts of the body, was not suitable for burns of the hand.

Open Grafting of Raw Surfaces. Dr. Bradford Cannon [49] presented a technique for the application of skin grafts to wounds following which no pressure was placed over the graft itself, nor was the graft sutured into place, the wound being treated as an exposed wound. In instances when this technique had been used on the hand, a wire cradle was provided for coverage to prevent bed clothes from coming in contact with the surface of the wound. The author stated that there was no need for the use of any type of coagulum, such as thrombin or chicken embryo extract, in order to facilitate an adherence between the graft and the surface of the wound; it was his feeling that there already existed on the wound surface all that was needed to cause the graft to adhere. The author pointed out a fact of particular interest, that the skin temperature is 2 to 4 degrees higher in a graft covered by pressure dressings than if the graft is left uncovered and exposed. The author presented this technique to show that in instances when there has been failure of previous grafting, or a desire to use exposure technique, this particular method of treatment can be utilized.

Dr. W. Brandon Macomber [50] discussed both of the papers on burns which had been presented. He agreed with Dr. Robertson's method of closed therapy versus open therapy for the burned hand; he said, however, that the Universal Chicago splint had not been uniformly satisfactory in his experience. He prefers the use of xeroform gauze directly over the burn wound to the use of petrolatum, feeling that there is less maceration.

At the time of grafting, Dr. Macomber's technique is to avulse the granulation tissue except where the granulation tissue covers joints or exposed extensor tendons. This allows a thicker graft to be applied than is

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[47] 76 West Adams Street, Detroit 26, Michigan.
[48] The Medical Arts Building, Toronto 5, Canada.
[49] 330 Dartmouth Street, Boston 16, Massachusetts.
[50] 149 Washington Avenue, Albany 6, New York.

possible over granulation tissue. He felt that thin grafts have a tendency to contract, and for this reason, secondary grafting is frequently necessary in order to relieve contractures. If it is possible to apply a thicker graft at the time of the initial grafting, less secondary work will be necessary. He prefers to apply pressure dressings to all of his grafts rather than to use the exposure technique. He believes that there is merit in a moist dressing on the recipient site when the moist dressing is placed over the xeroform gauze, since this offers a method of evaporation and, hence, cooling of the wound during the early phases of healing when the question of life or death of the graft is so critical.

Dr. Walter C. Graham [51], in discussing the two papers on burn therapy, pointed out the need for early closure of the burned hand by split-thickness skin grafts, with secondary resection of these grafts, and the application of thicker skin grafts or pedicle flaps where indicated.

Dupuytren's Contracture with Special Reference to the Pathology Involved. Dr. Robert E. Larsen [52] presented a comprehensive review of the subject of Dupuytren's contracture. His experience with ninety-nine cases seen in Detroit between 1949 and 1956 was presented. A statistical analysis of these cases showed that they conformed to the pattern previously established in other reports. The technique of the operation, the types of operation performed, and the postoperative results were discussed, and the results were found to be quite satisfactory. Attention was called to the relatively small number of Negroes found in the series. It was felt that this was statistically significant.

Numerous slides were shown with particular emphasis on the pathological findings. Theories as to the etiology of Dupuytren's contracture were discussed. In addition to the usual pathological changes found in the histological studies, Dr. Larsen called attention to the presence of iron pigment. This was found in nine of his specimens, and in each case the pigment was in an active proliferating area. He feels that it is not clear whether the iron pigment is associated with the cause of the lesion or is a result of the presence of the lesion. Dr. Larsen feels that the presence of the iron pigment certainly suggests old hemorrhage, associated with the actually proliferating fibrous tissue. He believes that this evidence of hemorrhage raises the question of whether or not trauma may be an etiological factor. He does not conclude that it is but considers that the subject is by no means closed. The author believes that surgery is the only form of treatment which will produce any lasting benefit. He concludes that the administration of tocopherols and irradiation may produce some temporary improvement and said that complete excision of the palmar fascia is indicated in most cases. With proper choice of operation and careful attention to operative details, excellent or good results can be expected in 80 to 90 per cent of the patients operated upon.

Surgical Repair of Dupuytren's Contracture. Dr. Darrel T. Shaw [53] showed an interesting motion picture demonstrating in detail the technique of the operative procedure of radical fasciectomy. The results in a few patients were also shown. The use of the proper type of incision was stressed. The Z-plasty incision at the base of the fingers was found to be particularly useful. This procedure was very clearly demonstrated and the results were impressive.

Dr. Julian M. Bruner [54] discussed the presentations of Dr. Larsen and Dr. Shaw. He said that Dr. Shaw's motion picture was the best he had ever seen and congratulated him on the film and on the technique demonstrated. He commented particularly on the use of the Z-plasty incision which he feels is very useful. It was pointed out, however, that there must be enough good subcutaneous tissues to support the blood supply of the transposed flaps.

In discussing Dr. Larsen's paper he commented on the fact which Dr. Larsen had mentioned, that patients with Dupuytren's contracture are prone to have stiffness of the hand after radical fasciectomy. He considers this condition to be more common in hands affected by Dupuytren's contracture. If it persists, it is disabling. Dr. Bruner believes that a less radical form of surgery than complete fasciectomy is occasionally indicated and feels that the selection of treatment for the individual case is important.

Dr. Henry W. Meyerding [55] congratulated Dr. Larsen on his paper and particularly on the pathological studies which he had conducted. He commented on his own series of 882 cases seen from 1928 to 1947. His statistics in general agreed with those of the author. Dr. Meyerding believes that local trauma may play an inciting role and certainly can aggravate a pre-existing condition. He related that he himself had had bilateral Dupuytren's contracture of the hand for over twenty years without any disability or obvious deformity. Progress of the disease ceased when he stopped using garden tools and old-fashioned cast cutters. He feels strongly that avoidance of trauma is important when the disease is first noticed. He believes that radical excision is a method of choice and stresses the importance of postoperative care which should be continued as long as necessary.

[51] 1421 State Street, Santa Barbara, California.
[52] 76 West Adams Avenue, Detroit 2, Michigan.
[53] 10525 Carnegie Avenue, Cleveland 6, Ohio.
[54] 1005 Bankers Trust Building, Des Moines 9, Iowa.
[55] 1531 6th Street, S.W., Rochester, Minnesota.

DR. SUMNER L. KOCH [56] also discussed Dr. Larsen's paper and commented on the finding of iron pigment. He felt that this might very likely be caused by the trauma associated with stretching a contracted finger. He also commented that he believes compression dressings are valuable for the prevention of postoperative venous congestion and oedema in the hand.

DR. JOSEPH H. BOYES [11] commented on the relative rarity with which the lesion is seen in a Negro.

[56] 154 East Erie Street, Chicago 11, Illinois.

ALABAMA ORTHOPAEDIC SOCIETY

AS REPORTED BY ROBERT T. KING, M.D., *Secretary*, MOBILE, ALABAMA

The 1956 meeting of the Alabama Orthopaedic Society was held at the Crippled Children's Hospital, Birmingham, Alabama, on April 18, 1956.

The Scientific Program was as follows:

The Effects upon Leg-Length Inequality of Arrest or Stimulation or both of the Epiphyses at the Knees. DR. M. A. ACCINNO [1] reported the results seen at follow-up examination six years after treatment. Epiphyseal stimulation had been employed in twenty-three cases; stapling and stimulation had been performed simultaneously in twenty-three cases and epiphyseal arrests had been carried out in thirty-four cases, six by the Phemister method and twenty-eight by stapling. The results from stimulation were poor, with an average increase of only 0.023 inch.

Epiphyseal stapling had been followed by a number of complications, the major ones being knock-knee (14 per cent), bow-leg (10 per cent), genu recurvatum (28 per cent), and overgrowth of the opposite leg. The Phemister type of epiphyseodesis was the most satisfactory method.

Chondromalacia of the Patella. DR. IRVING CAHEN [2] presented an end-result study of 150 cases of chondromalacia of the patella. As a result of his study, he felt that conservative treatment should be tried first, but said that in a large proportion of the patients patellectomy was finally resorted to. The functional results of patellectomy had been quite satisfactory.

Following the two papers a number of case reports and roentgenographic demonstrations were presented by various members of the society.

The following officers were elected for the ensuing year:

President: Dr. T. J. Bender, Mobile;

Vice-President: Dr. Elias Kaiser, Montgomery;

Secretary-Treasurer: Dr. Robert T. King, Mobile.

Dr. Jack Hughston of Columbus, Georgia, and Dr. Wendell Newcomb, Pensacola, Florida, were elected associate members.

[1] 811 South 20 Street, Birmingham, 5, Alabama.

[2] 3705 Prytania Street, New Orleans 15, Louisiana.

ROBERT BAYLEY OSGOOD
1873–1956

Robert Bayley Osgood, A.B., M.D., Sc.D. (Hon.), F.A.C.S., F.R.C.S. (Hon.), died October 2, 1956, in Boston at the age of eighty-three. The funeral services were held at St. Paul's Cathedral where he had worshiped regularly until 1945, when illness made further attendance impossible. Among those present at the services were many medical colleagues and orthopaedic surgeons. There were only a few who could have spoken of the position he occupied when at the summit of his career, of the role he had played in helping to develop the specialty of orthopaedic surgery, or of the inspiration he had been to young orthopaedic aspirants. Although he had outlived most of his contemporaries, his reputation survived.

Robert Osgood, or Bob, as he was always known to his friends, was of good New England stock. He was born in Salem, Massachusetts, July 6, 1873, the son of John Christopher and Martha Ellen (Whipple) Osgood. His line could be traced back to John Osgood who emigrated from Hampshire, England, to Andover, Massachusetts, in 1638.

Following an education in the public schools of Salem, Robert Osgood was admitted to Amherst College from which he was graduated in 1895 after the usual classical training in Greek, Latin, and English literature. While in college his chief outside interests were dramatics and singing with the glee club; these interests he retained throughout his life. He was listed in his senior year as an independent in politics, a Congregationalist, and a candidate for medical school. What inspired him to enter medicine is not known. The decision would appear to have been made late, for in those days it was rare for a man who was going to study medicine to

obtain a classical education. This gave him the broad intellectual outlook he later had toward every aspect of life, professional or domestic, and made him a delightful companion. He loved poetry and could quote from it for hours. He also loved music and had good musical understanding, although he played no instrument until in later years, when he learned to play the flute and fife for amusement.

He was granted his degree from Harvard Medical School in 1899. During his last year in medical school he served as a student intern at the House of the Good Samaritan. This institution was devoted to the care of patients with chronic diseases and, at that time, was, to a large extent, filled with tubercular patients; among these were many with tuberculous joint disease. Undoubtedly, it was from assisting such orthopaedic surgeons as Edward Bradford, Elliott Brackett, and Joel E. Goldthwait in the care of these patients that he became interested in orthopaedic surgery. Following graduation, he served a surgical internship at the Massachusetts General Hospital. This was considered a full qualification for the practice of surgery.

At that time the first machines for clinical roentgenographic study were introduced, following Roentgen's great discovery of x-rays in 1895. We can easily imagine how Robert Osgood, with the eagerness of

Robert Osgood with Sir Robert Jones and his beloved dogs (ca. 1920).

youth and with the background of his orthopaedic experience at the House of the Good Samaritan, where the diagnosis of bone and joint conditions was based only on clinical examinations and impressions, would become interested in this new tool which offered the possibility of more exact diagnosis. He formed a friendship with Walter J. Dodd, the pharmacist at the Massachusetts General Hospital, who, for lack of a better qualified person, had undertaken to make the first experiments in the use of the x-ray machine. Together they explored its value as a diagnostic aid. After finishing his internship, his first hospital appointment was that of roentgenologist at the Boston Children's Hospital in 1902 and 1903. It was while working there that he made the observations on the growth and traumatic disturbances of the tibial tubercle during adolescence which were published in a paper on January 29, 1903. These lesions have since become known as Osgood-Schlatter disease, Schlatter having at a later date also described the condition. The early association with W. J. Dodd also gave rise to a paper under their joint authorship in 1906 on the technique and interpretation of roentgenograms as applied to surgery. Fortunately, Robert Osgood's roentgenological work was of short duration because Dodd, who remained active in the field, and indeed was one of its great pioneers, incurred skin cancers of the hands which ultimately proved fatal. Bob Osgood also had many skin cancers of the hands. He underwent several operations and a cure resulted. He died of cerebral vascular disease.

In 1903, Robert Osgood went to study in Germany, France, and England; in England he made the acquaintance of Hugh Owen Thomas and his nephew Robert Jones, whose work made a deep impression on him. On his return, he became associated with Dr. Joel E. Goldthwait and Dr. Charles F. Painter in the practice of orthopaedic surgery. He was made Assistant Orthopaedic Surgeon at the Carney Hospital and, in 1906, Assistant Orthopaedic Surgeon at the Massachusetts General Hospital. He participated with Dr. Goldthwait and Dr. Painter in the writing of one of the first American books on orthopaedic surgery entitled *Diseases of*

the Bones and Joints. He was deeply interested in research; his work at that time included studies of metabolism in patients with rheumatoid arthritis and, later, in association with Dr. William B. Lucas, studies of the transmission of the virus of poliomyelitis. They demonstrated that the virus of poliomyelitis might remain latent in the nasopharyngeal lymphoid tissue of monkeys for six months after the acute symptoms of the disease had disappeared and that it still could be transmitted to other monkeys. Later they were able to demonstrate for the first time a case of a human carrier of poliomyelitis by means of the recovery of virus from the nasal washing of a patient who had experienced an attack of poliomyelitis four months previously.

With the development of an orthopaedic in-patient service at the Massachusetts General Hospital in 1911, following the successful efforts of Dr. Goldthwait in raising funds to build Ward I, Bob Osgood's clinical work was centered in the Massachusetts General Hospital. At about this time he became instructor of surgery at the Harvard Medical School.

In 1910, in collaboration with Dr. Samuel J. Mixter, he reported the first open reduction of dislocation of the atlas on the axis, the reduction being maintained by fixation with a strong silk suture. This operation

Reunion (ten years) of the Medical Staff of the Harvard Unit of the American Hospital in Neuilly. Eliot Cutler is missing. Standing, left to right, are: Fred Coller, Lyman Barton, George Bennett, Orvill Rogers, Philip Wilson, and Marius Smith-Petersen. Sitting, left to right, are: Beth Vincent, Robert Greenough, Harvey Cushing, and Robert Osgood.

forecast the pattern of the operation that has since been followed, only the silk suture has been replaced by stainless-steel wire and fusion has been combined with the fixation.

The First World War presented a great challenge to medical science in meeting the emergencies and needs of caring for thousands of wounded. When the French and British armies were locked in trench warfare with the Germans along the Belgian and French frontiers in 1915, there was formed a Harvard surgical unit to work in rotation with other American university units at the American Ambulance in Neuilly. This unit, headed by Harvey Cushing, with Robert Osgood as orthopaedic surgeon, was soon at work. The experience, brief as it was, was enough to convince Bob Osgood of the frequency and importance of wounds of the extremities involving skeletal structures caused by machine-gun fire and high-explosive shells and of the need for experienced orthopaedic surgeons to provide the necessary expert care.

History moved forward rapidly; it was soon evident that American troops would be in action in the European Theater of war. Bob Osgood was not alone in foreseeing the need for the immediate training and preparation of American orthopaedic surgeons to meet the responsibilities of providing care for American casualties. Thanks to the initiative and support of other American orthopaedic surgeons and particularly to the cooperation of Robert Jones, who at this time held the rank of Colonel in the Royal Army Medical Corps and who had been made responsible for the care of all those with injuries of the musculoskeletal system in the British Army, arrangements were made so that it was possible, as soon as the United States entered the war, to enroll a group of orthopaedic surgeons in the American Army and to send them to Great Britain to assist in the care of British wounded. There they learned the methods of treatment which had proved most successful. In due course, after the arrival of American troops in France and their introduction into combat, these American orthopaedic surgeons were relieved of their duties in Britain and were transferred for active duty with the American Expeditionary Forces.

Bob Osgood obtained his commission in the Army as soon as the United States entered the War; and, after serving with the Army Medical Board appointed in 1917 to standardize splints, appliances, and surgical dressings for the American Expeditionary Forces, he was transferred to the British Medical War Office in London, where he served six months as deputy to Major General Sir Robert Jones, Chief of the Orthopaedic Section of that Service. This assignment brought him into close personal relationship with Sir Robert Jones whom he quickly learned to love. Indeed, it was because of the friendly relations he established with the British orthopaedic surgeons that he was able, at the end of the war, to help in the founding of The British Orthopaedic Association, which had seemed impossible previously, largely because of local rivalries and failure to attain unity of purpose and understanding. Full acknowledgement has been made by some of the founding members of this Association of the unique role played by Robert Osgood in its formation. He was made one of its first honorary members. In February 1918, Robert Osgood was attached to the office of the Chief Surgeon of the American Expeditionary Forces at Tours where he served as a deputy to Col. Goldthwait, who was then responsible for development of the Army orthopaedic service under the Chief Surgeon. Later Bob Osgood was recalled to the United States to serve as Orthopaedic Consultant to the Surgeon General. In this position he did valuable work through periodic visits to the large base hospitals in the United States where he was able not only to examine the quality of the work being done but also, because of his large experience, to help in the solving of individual problems. He was discharged in 1919 with the rank of Colonel in the Medical Reserve Corps.

Upon returning to Boston and upon the retirement of Dr. Elliott Brackett, Bob Osgood was promoted to Head of the Orthopaedic Service of the Massachusetts General Hospital. His weekly orthopaedic rounds were stellar performances, not so much because of what he said, but because of the opportunity he offered to all staff members for full discussion. Ultimately he summarized the discussions which clearly guided the final decisions as to treatment. He operated only often enough to maintain his technical skill, feeling always that the surgical opportunities should be given to the junior staff surgeons. He devoted himself to his residents, learning to know them and their families personally, so that he was familiar with all their problems. When a man did not come up to the standards required, he redoubled his efforts in the hope that he would find a way to stimulate him and set him on the right path. He was able to arrange the incorporation of the orthopaedic resident training programs of the Massachusetts General Hospital and the Boston Children's Hospital into a single program under the aegis of Harvard Medical School. This gave a twelve-month residency at each of the two institutions and a six-month training period in the basic sciences at Harvard Medical School. It was the most advanced and comprehensive program of orthopaedic training in the United States and served as a model for many other medical schools.

One of his major achievements was the organization of the first conference on the treatment of fractures, a two-day meeting which was held at the Massachusetts General Hospital in 1921. This represented a triumph of diplomacy and leadership because it brought together for the first time general surgeons who were interested in fractures and orthopaedic surgeons. The conference was attended by fifty or more general and orthopaedic surgeons of great individuality and reputation. It seemed impossible that such men as Ashley Ashurst of Philadelphia, William Sherman of Pittsburgh, Charles Scudder of Boston, Kellogg Speed of Chicago, to name only a few, could get together with a group of orthopaedic surgeons and achieve a meeting of the minds on the treatment of fractures; yet, this was accomplished and the results were published in a bulletin of the American College of Surgeons entitled *A Primer of Fracture Treatment*. This was reprinted many times and was later translated into many foreign languages. From this first meeting emerged the Fracture Committee of the American College of Surgeons, an organization on a national scale which was established to improve both the emergency care and the final treatment of fractures. This Fracture Committee has since been expanded to become the Committee on Trauma of the American College of Surgeons.

In 1922, Bob Osgood left the Massachusetts General Hospital and became Chief of the Orthopaedic Service at the Boston Children's Hospital; this carried with it the title of Professor of Orthopaedic Surgery at the Harvard Medical School. In 1924, he was made John B. and Buckminster Brown Professor of Orthopaedic Surgery, a permanently endowed chair. In accepting this appointment, Bob Osgood insisted upon and obtained a concession from the Dean and Faculty of Medicine of the Harvard Medical School that henceforth

eligibility for the title of Professor of Orthopaedic Surgery should not be limited exclusively to the Chief of the Orthopaedic Service at the Boston Children's Hospital but that it should also be extended to the Chief of the Orthopaedic Service at the Massachusetts General Hospital. He held this post until 1930, when he retired voluntarily, earlier than necessary, in order to make room for a younger man.

Dr. Osgood was a member of the Massachusetts Medical Society, the American Medical Association, the New England Surgical Society (Past-President, 1928–1929), The American Orthopaedic Association (President, 1920–1921), The American Academy of Orthopaedic Surgeons, and the American College of Surgeons. In 1925, he served as Hugh Owen Thomas Lecturer at the Medical Institute of Liverpool. He was a member of the International Society of Orthopaedic Surgery and Traumatology, Honorary Member of the Royal Society of Medicine in England, Honorary Member of The British Orthopaedic Association, and Honorary Member of The Australian Orthopaedic Association. As a member of the American Committee on Rheumatism he helped to organize the American Rheumatism Association (President, 1944). He was the first Chairman of the Advisory Board of Orthopaedic Surgeons to the Trustees of the Shriners' Hospital for Crippled Children. He was a member and later Chairman of the Advisory Committee for Services for Crippled Children of the Children's Bureau. He was a member of the Advisory Board of the Alfred I. duPont Institute and helped in planning its hospital. In 1943, he was made an Honorary Fellow of the Royal College of Surgeons, the Fellowship being conferred on him by Major General Sir William Heneage Ogilvie at the British Embassy in Washington. He was awarded the degree of Doctor of Science, *honoris causa*, by Amherst College in 1935.

His former pupils and associates combined on the occasion of his seventieth birthday to publish in the *Archives of Surgery* a sepcial number dedicated to him; in the following year another group of pupils and associates united to arrange for the painting of his portrait by Mr. Samuel Hopkinson. This excellent work now hangs in the Massachusetts General Hospital.

Dr. Osgood was married on April 29, 1902, to Margaret Louisa, daughter of Nathaniel Gates Chapin of Brookline, Massachusetts, who survives him. They have a daughter by adoption, Ellen, who is now Mrs. Frederic Jennings and there are four grandchildren. Bob and Margaret Osgood were exponents of the art of gracious living, of cordial hospitality, and of warm friendship. Many are the friends who can think back to pleasant evenings in their house on Beacon Hill, Boston, or to happy days and weekends at their seaside home in Ipswich, Massachusetts.

P. D. W.

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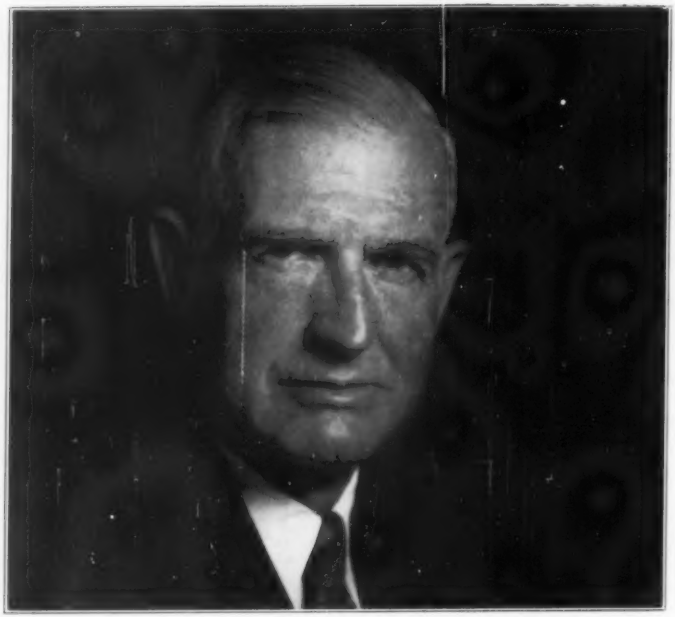

JOHN CREE WILSON, SR.

1888–1957

Dr. John Cree Wilson died on January 9, 1957, after a long life devoted to the crippled and injured and to medical education. His conduct always emanated dignity and greatness, and at no time in his life were these qualities more evident than at the end of his long career. No greater test of character exists than the manner in which a man faces death. This test he met with the same dignity and cheerfulness with which he faced every situation in life. Aware for several weeks that it was impossible to recover from his illness, he carried on with equanimity, devoting all the energies of his mind to the advancement of medical education at the School of Medicine of the University of Southern California, of which he was a Trustee.

Dr. Wilson was born December 14, 1888, in Santa Ana, California, and received his early education in the public schools of Santa Ana. He was graduated from the University of California in 1908 and received his doctorate in medicine from the University of California School of Medicine, San Francisco, in 1912. He entered general practice in Hollywood, then a small community near Los Angeles. In 1916 he married Anna Grant; from this union three sons were born. In 1938, after the death of his wife, he married Marjorie Connell Welch.

A short time in practice convinced him that the one-year internship did not give him the skill and knowledge which he felt requisite for the care of his patients. In 1916 he discontinued practice and went to Boston, where he entered postgraduate training in orthopaedic surgery at the Massachusetts General Hospital, under the aegis of the Harvard Medical School. As he was completing his training in orthopaedic surgery, the United States entered World War I. Entering the Army, he was stationed at General Hospital No. 6 at Fort MacPherson, Atlanta, Georgia. His ability to lead and to instruct others soon became evident; before the end of World War I, he was given the task of training general surgeons in orthopaedic techniques to meet the needs of the rapidly expanding Medical Corps of the Army. There are many men practicing today who still recall his lucid and enthusiastic teaching.

Late in 1919, he began to practice orthopaedic surgery in Los Angeles. He devoted much time to the Los Angeles General Hospital, where his ability in organization contributed much to the development of orthopaedic surgery. He also became associated with the Children's Hospital of Los Angeles, in which his interest never flagged. In 1926, he became Chief of the Orthopaedic Division of the Children's Hospital and remained active in this position until 1955. During this period he was instrumental in the development of an outstanding orthopaedic service which especially emphasized the resident-training program. A residency in this service was sought after by young orthopaedic students from all over the United States. His Thursday morning conference, which he never missed, was attended not only by orthopaedic surgeons but by men in other specialties from Southern California; indeed, visiting orthopaedic surgeons from all over the United States made it a point to attend this conference. His conduct of it exemplified both the character of the man and his worth as a teacher.

There were no *ex cathedra* pronouncements by the Chief, but rather an opportunity for each resident and attending staff member to state his viewpoint and opinions, which were deferentially sorted, analyzed, and coordinated by the Chief. As a result of this training there are many orthopaedists who can start with facts and arrive at a logical conclusion, rather than give as a justification of their treatment the fact that they do as the Chief did. From 1947 to 1950, he was Chairman of the Medical Staff of Children's Hospital, during which time he worked closely with the Board of Trustees. His vision and influence were the greatest factors in the development of this hospital into an outstanding medical center for children. His efforts were largely responsible in bringing the Connell Clinic and private pavilion from a dream to a reality.

In 1929, when the University of Southern California determined to reactivate its defunct School of Medicine, it was evident that the success of this project would be dependent, at least during its early years, on the generous and enthusiastic support of the practicing physicians in Los Angeles. It was natural that Dr. Wilson should be called upon to help with this effort. In 1930, he was appointed Professor of Orthopaedic Surgery. With the decision which characterized him, he immediately obtained the support and cooperation of the well qualified orthopaedic surgeons of the city and formed a strong department which has been able to fulfill its function even in the face of difficulties, such as depletion of personnel by war. Through his individual efforts, fiscal support, which a budget did not supply, was obtained for the department to enable it to maintain the quality of the teaching. He served as Professor of Orthopaedic Surgery until 1952, when he was called to be a Trustee of the University. This required that he relinquish active teaching, which he did reluctantly because he felt it possible to advance the School of Medicine more as a Trustee of the University than as a teacher. From 1952 until the time of his death, he voiced the cause of the School of Medicine to the Trustees with great influence.

Many well deserved honors came to him during his active life, none of which seemed to impress him much. He was honored by membership in The American Orthopaedic Association in 1928. With the establishment of specialty boards in the late 1920's, it was natural that the orthopaedic specialty should turn to him for leadership. In 1934 he was a founder of the American Board of Orthopaedic Surgery, serving continuously with the Board through its first eight years and retiring from the Board in 1941, after it had reached a healthy position. In 1938, he was President of The American Academy of Orthopaedic Surgeons, the first man from the West to hold high office in a national orthopaedic association. He held membership in the International Society of Orthopaedic Surgery and Traumatology. For many years he was Chairman of the Medical Advisory Board of the Shriners' Hospital for Crippled Children, a position requiring much time and effort, which he filled to the time of his death. He was honored by many local medical and scientific societies with the office of their presidency.

Dr. Wilson took active part in the scientific activities of orthopaedic societies, contributing timely, worthwhile, and well considered papers. His essays on acute hematogenous osteomyelitis, calling attention to a necessity for a consideration of the physiological status of the patient and its importance in reducing mortality from surgery were published well in advance of the present knowledge of fluid balance. Other sound essays on fracture of the neck of the femur in children and on posterior dislocation of the shoulder evidenced the variety of his interest and experience. His discussions of other men's works, while often differing, were always a kindly expression of a different experience and always added to the original work.

His devoted wife, Marjorie Wilson, and three sons, Dr. John Cree Wilson, Jr., Dr. Lewis Grant Wilson, and Richard Alexander Wilson, survive him. Scores of young orthopaedic surgeons whose minds he cultivated and whose path he made easier revere him and a large number of patients, to whom he was far more than a surgeon, fondly remember him.

News Notes

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held at the Waldorf-Astoria Hotel in New York City, February 1 through 6, 1958.

The Fourth International Poliomyelitis Conference of The International Poliomyelitis Congress will be held in Geneva, Switzerland, July 8 to 12, 1957.

The **Gordon Research Conference** on Chemistry, Physiology, and Structure of Bones and Teeth will be held July 15 to 19, 1957, at Kimball Union Academy, Meriden, New Hampshire.

The next Annual Meeting of the **Western Orthopedic Association** will be held in Santa Barbara, California, October 20 through 24, 1957.

The **Texas Orthopaedic Association** held its Annual Meeting April 29, 1957, at the time of the State Medical Meeting in Dallas, Texas. The following were elected to office:

President: Margaret Watkins, M.D., Dallas;
Vice-President: Duncan McKeever, Houston;
Secretary-Treasurer: B. C. Halley, Dallas.

It was unanimously voted at the meeting to make a contribution to The Orthopaedic Research and Education Foundation.

The Annual Meeting of **The American Fracture Association** will be held in El Paso, Texas, September 30 through October 2, 1957. In conjunction with this meeting the University of Texas will offer a one-day course on fractures on Sunday, September 29, 1957.

KAPPA DELTA AWARD

The American Academy of Orthopaedic Surgeons announces that manuscripts for the Kappa Delta Award are earnestly solicited. This award is presented annually for the outstanding contribution in the field of orthopaedic surgery. Manuscripts should be forwarded to Dr. Carroll B. Larson, Chairman of the Committee on Scientific Investigation, University Hospital, Iowa City, Iowa. By custom, the winner of the award will present his paper at the next Annual Meeting of The Academy in February 1958. It is necessary that manuscripts be received on or before July 1, 1957, so that they may be properly evaluated and forwarded to the Executive Committee for approval.

Dr. J. E. M. Thomson of Lincoln, Nebraska, was honored with the honorary degree of Doctor of Science by Ohio Wesleyan University. In his address, Dr. Thomson, grandson of the University's first President, told students at the University that their education must be one of inquiry rather than one of reception.

Dr. Julius Haas was awarded the Umberto I medal by the Istituto Ortopedico Rizzoli, Bologna, Italy, for his monograph *Congenital Dislocation of the Hip.*

Dr. Vaclav Cizek, Prague, Czechoslavakia, first assistant in the Clinic of Prof. Zahradnicek (First Orthopaedic Clinic of Charles University) died suddenly of a coronary infarction at the age of forty-nine.

The Seventh International Cancer Congress will be held in London, England, July 6 to 12, 1958, under the Presidency of Sir Stanford Cade. Congress headquarters will be The Royal Festival Hall. There will be two main sessions of the Congress: experimental, and clinical and cancer control. Special emphasis will be placed on hormones and cancer, chemotherapy, carcinogenesis, and cancer of the lung. Registration forms and a preliminary program will be available early in 1957 on application to The Secretary General, Seventh International Cancer Congress, 45 Lincoln's Inn Fields, London, W.C. 2, England.

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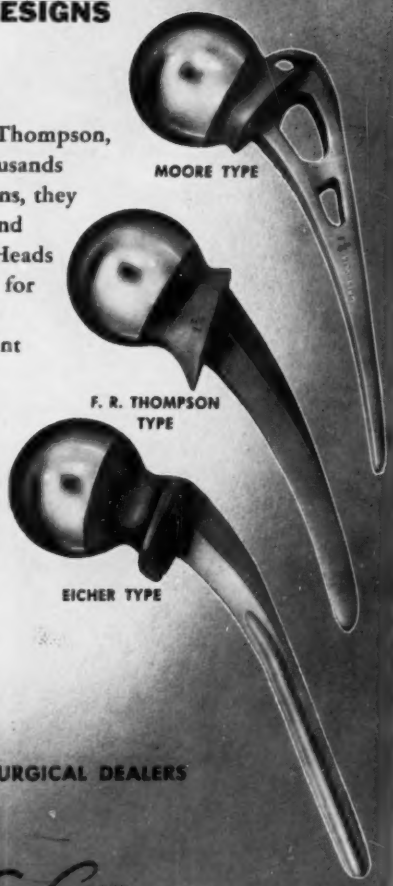

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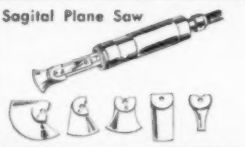

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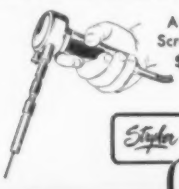

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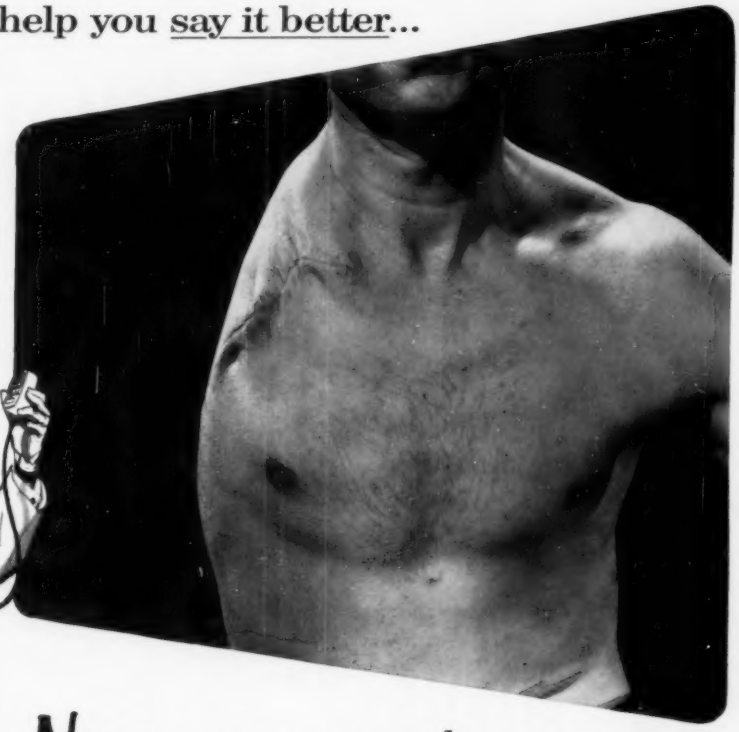

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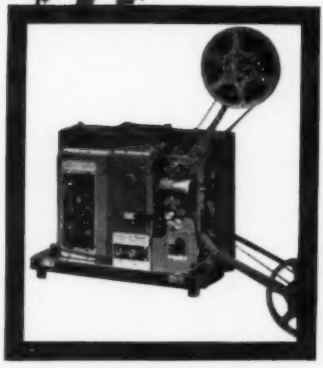

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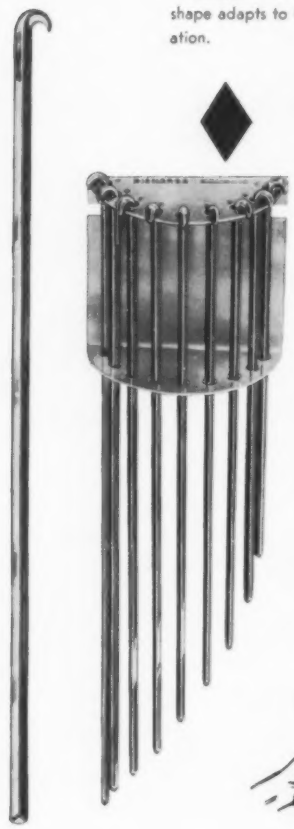

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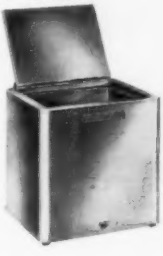

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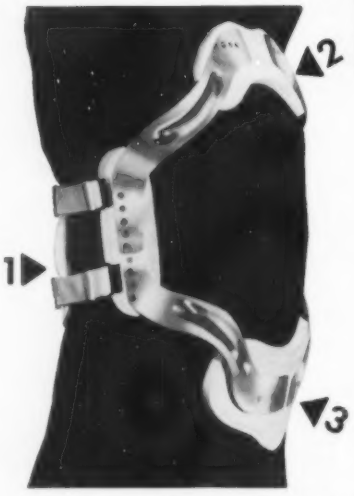

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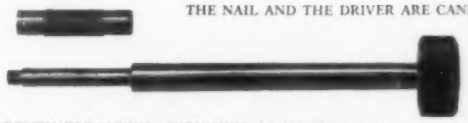

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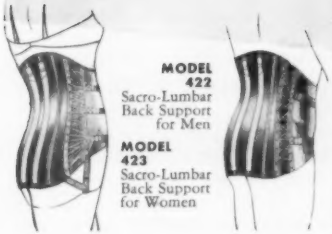

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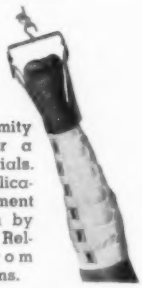

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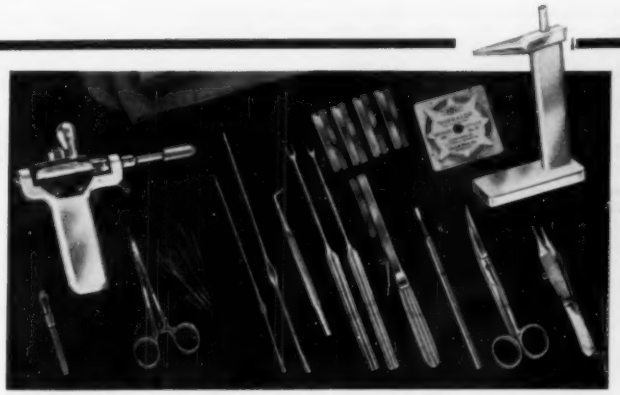

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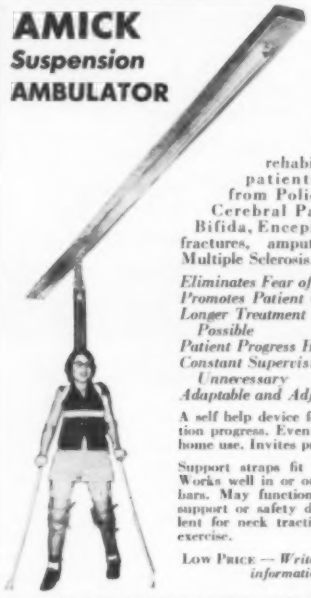

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